Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	)	GN Docket No. 14-177
	)	
Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands	)	RM-11809

COMMENTS OF ELEFANTE GROUP, INC.

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SUMMARY

In May of this year, Elefante Group, Inc. ("Elefante Group") filed its Petition for Rulemaking ("Petition") to establish a Stratospheric-Based Communications Service ("SBCS") utilizing the 21.5-23.6, 25.25-27.50, 71-76, and 81-86 GHz Bands (collectively, "the SBCS Bands") on a co-primary and non-exclusive basis that would operate compatibly with both Federal and non-Federal incumbents ("Petition"). In response to the Third Further Notice of Proposed Rulemaking ("Third FNPRM") in the Commission's *Spectrum Frontiers* proceeding (GN Docket No. 14-177), Elefante Group urges the Commission in its Comments to consolidate the *Petition* with the *Spectrum Frontiers* proceeding to allow comprehensive consideration of SBCS use of not only the 25.25-27.5 GHz (the "26 GHz Band") raised in the *Third FNPRM*, but the other SBCS Bands as well. At the same time, the Commission should move cautiously when considering permitting the Upper Microwave Flexible Use Service ("UMFUS") to access the 26 GHz Band. Such use should be authorized only if it is clear UMFUS can operate compatibly with incumbent services and with SBCS.

Over the past twenty-seven months, the Commission has taken multiple steps to make available tremendous amounts of spectrum for the commercial mobile industry in the millimeter wave ("mmW") bands in this proceeding. Later this year, the first auctions of mmW spectrum for the UMFUS will take place, and three more auctions are anticipated next year. The United States clearly has been an international leader in making "high band" spectrum available to interested commercial carriers; in fact, it has forged ahead while much of the world continues to examine the issue and wait for the results of Agenda Item 1.13 of the World Radiocommunication Conference in November 2019 ("WRC-19").

Elefante Group submits that the United States has the opportunity to lead the world in another innovative and ground-breaking area essential to successful and rapidly-deployed next-generation networks and services, namely stratospheric-based communications. Elefante Group appreciates that the Commission promptly put the *Petition* out for public comment. Elefante Group respectfully urges the Commission to continue along this path and consolidate the consideration of a SBCS regulatory framework in this *Spectrum Frontiers* proceeding, so as to accelerate review of the matter and the adoption of rules which will lead to an early deployment of SBCS solutions and the public benefits that would bring. Taking these steps will not only fulfill Section 7 of the Communications Act of 1934, as amended (the "Act"), mandating prompt action on requests to establish new services and technologies, but will also further the fundamental purpose of the Act and one of the central obligations of the Commission: "to make available, so far as possible, to all the people of the United States . . . a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges."

In the *Third FNPRM*, the Commission, among other things, seeks comment about the future use of the 26 GHz Band, requesting views on whether it should be made available for flexible mobile use, *i.e.*, UMFUS, and the compatibility of UMFUS with incumbent and new services, including SBCS. The *Third FNPRM* recognizes SBCS as a prospective new service in the 26 GHz Band and inquires whether it should limit the provision of SBCS in the band to exclusive-use UMFUS licensees or, as another option from among others, preclude UMFUS from accessing the band.

Elefante Group reiterates in Section II of its Comments why the 26 GHz Band is an essential SBCS Band. It was selected by Elefante Group after a comprehensive review of spectrum between 17.0-43.5 GHz as the best candidate for downlinks from stratospheric platform stations ("STRAPS") to fixed ground-based user terminals ("UTs"). If there is to be an SBCS in this country, providing high-capacity, low-latency solutions to help accelerate widespread next generation networks, Internet of Things ("IoT") capabilities, and other innovative services and applications, Elefante Group submits that co-primary access to the 26 GHz Band is a key element to facilitating that outcome.

In Section III of its Comments, Elefante Group discusses why, in contrast to the importance of the 26 GHz Band to the realization of SBCS, access to the Band for the mobile industry is not a key enabler for the deployment of 5G services within the commercial mobile industry for ground-based deployments, or a band necessary for international harmonization of 5G spectrum bands. This is because of the large amounts of spectrum already made available for UMFUS – including 24.25-24.45 and 24.75-25.25 GHz (collectively, the "24 GHz Band") as well as 27.5-28.35 GHz (the "28 GHz Band") – and the more than four additional gigahertz of spectrum still under consideration for UMFUS in this proceeding. Other purported benefits of making this spectrum available for exclusive-use UMFUS are exaggerated.

Elefante Group, supported by three new compatibility analyses conducted by Lockheed Martin, demonstrates in Section IV of the Comments that the introduction of UMFUS into the 26 GHz Band would raise very serious compatibility issues for incumbents and new services such as SBCS. Elefante Group examines why the studies concerning the compatibility of International Mobile Telecommunications ("IMT") with other services that have been performed in connection with Agenda Item 1.13 for WRC-19 fall short of describing the true potential for harmful interference arising from the introduction of UMFUS into the 26 GHz Band. As Elefante Group observes, these studies (the "ITU Studies") are limited to a single use case for

IMT which is particularly benign as a potential interferer in comparison with the full range of operational options available to UMFUS operators, such as higher power, broader configurations and antenna characteristics, types of service applications and resulting configurations, and other parameters which would adversely affect compatibility. The ITU Studies also make unwarranted assumptions, such as ubiquitous dense urban clutter loss and time-variant factors which mask the true potential for harmful interference to the Fixed Service ("FS"), Aeronautical Mobile Service ("AMS"), Earth Exploration Satellite Service ("EESS"), Space Research Service ("SRS"), and SBCS applications in localized settings. Nonetheless, even the ITU Studies begin to reveal the potential for incompatibility without specific regulatory constraints on UMFUS.

In response, the analyses of Elefante Group and Lockheed Martin correct for these unwarranted assumptions and demonstrate how, simply by using permitted UMFUS power levels rather than those lower powers examined in the ITU Studies, the potential for harmful interference to incumbents increases several-fold. Further analysis considering the various operational degrees of freedom that UMFUS operators would have would only magnify the serious concerns about the incompatibility of UMFUS operations in the band.

Elefante Group also examines the potential for flexible mobile to share the same band with SBCS, as requested by the *Third FNPRM*, with equally sobering results. While SBCS will protect against harmful interference into UMFUS base stations and user equipment by adhering to a well-established power flux density ("PFD") limit to protect ground-based services that already applies to other overhead space services in the Ka-Band, UMFUS base stations would present a significant degree of incompatibility with the deployment of SBCS UTs. Despite the indications that UMFUS cannot operate on a compatible basis with incumbent services and SBCS, Elefante Group will continue to explore this matter, and welcomes dialogue with the commercial mobile industry, to evaluate whether practical coordination and cooperation measures exist that might sufficiently alleviate the interference threats from UMFUS.

In Section V, Elefante Group addresses the Commission's queries on whether SBCS should be limited in the 26 GHz Band to UMFUS operators with exclusive-use, geographic-based licenses. Elefante Group submits that such a step would likely severely restrict the introduction of SBCS in this country. Both the small amount of 26 GHz Band spectrum available to individual exclusive-use licensees and the probable limited geographic scope of UMFUS licenses would make it unlikely that advanced SBCS systems capable of serving both urban and rural areas with high-throughput, wide-area solutions would be launched. As a result, many of the benefits that SBCS offers may never be achieved. Rather, Elefante Group submits that its wholesale vision for SBCS in its *Petition* is the right one to make this new, essential service a reality, and to do so in a way that is truly compatible with incumbent operations.

Finally, in Section VI, Elefante Group discusses why, procedurally, the Commission should consolidate consideration of the *Petition* and adoption of SBCS rules in all of the SBCS Bands with the evaluation of future uses of the 26 GHz Band in this proceeding. As Elefante Group explains, this likely would require a new Further Notice of Proposed Rulemaking (unless the Commission believes the *Third FNPRM* can be clarified so as to obviate the need for such a Further Notice). Taking this step will not only accelerate the adoption of an SBCS regulatory framework, it will help facilitate a timely deployment of next-generation communications and IoT solutions to a larger portion of the American public by operators in all spectrum bands. As such, consolidation of the *Petition* with this rulemaking will enable the Commission to meet its obligations under Elefante Group's Section 7 request, included in the *Petition*, whereby Elefante Group sought the institution of a rulemaking within one year of the filing of the *Petition*.

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COMMENTS OF ELEFANTE GROUP, INC.

Elefante Group, Inc. ("Elefante Group"), by its attorneys, hereby provides comments in response to the Commission's Third Further Notice of Proposed Rulemaking ("Third FNPRM") in its *Spectrum Frontiers* proceeding in GN Docket No. 14-177.[1]

I. INTRODUCTION AND SUMMARY

Over the past twenty-seven months, the Commission has taken multiple steps to make available tremendous amounts of spectrum for the commercial mobile industry in the millimeter wave ("mmW") bands in this proceeding. Later this year, the first auctions of mmW spectrum for the Upper Microwave Flexible Use Service ("UMFUS") will take place, and three more auctions are anticipated next year. The United States clearly has been an international leader in making "high band" spectrum available to interested commercial carriers; in fact, it has forged

[1] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services*, GN Docket No. 14-177, WT Docket No. 10-112, Third Report and Order, Memorandum Opinion and Order, and Third Further Notice of Proposed Rulemaking, FCC 18-73 (June 8, 2018) ("*Third FNPRM*").

ahead while much of the world continues to examine the issue and wait for the results of Agenda Item 1.13 of the World Radiocommunication Conference in November 2019 ("WRC-19").

The United States has the opportunity to lead the world in another innovative and ground-breaking area essential to next-generation networks and services, namely stratospheric-based communications. Elefante Group filed a Petition for Rulemaking ("Petition") in May of this year to establish a Stratospheric-Based Communications Service ("SBCS") utilizing the 21.5-23.6, 25.25-27.50, 71-76, and 81-86 GHz Bands (collectively, "the SBCS Bands") on a co-primary and non-exclusive basis operating compatibly with both Federal and non-Federal incumbents.[2] The Commission took the next step by promptly putting the *Petition* out for public comment.[3] Elefante Group respectfully urges the Commission to continue along this path and consolidate the consideration of an SBCS regulatory framework in this *Spectrum Frontiers* proceeding, so as to accelerate review of the matter and the adoption of rules which will lead to an early deployment of SBCS solutions and the public benefits that would bring. Taking these steps will not only fulfill Section 7 of the Communications Act of 1934, as amended (the "Act"), mandating prompt action on requests to establish new services and technologies,[4] but will also further the fundamental purpose of the Act, and one of the central obligations of the Commission: "to make available, so far as possible, to all the people of the United States . . . a

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2 *Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands*, Petition for Rulemaking, RM-11809 (May 31, 2018) ("*Petition*").

3 *Consumer & Governmental Affairs Bureau Reference Information Center Petition for Rulemakings Filed*, Public Notice, Report No. 3093 (June 11, 2018) ("*Petition Public Notice*").

4 47 U.S.C. § 157.

rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges."[5]

In the *Third FNPRM*, the Commission, among other things, seeks comment about the future use of the 25.25-27.5 GHz band (the "26 GHz Band"), requesting views on whether it should be made available for flexible mobile use, *i.e.*, UMFUS, and the compatibility of UMFUS with incumbent and new services, including SBCS.[6] The *Third FNPRM* recognizes SBCS as a prospective new service in the 26 GHz Band and inquires whether it should limit the provision of SBCS in the band to exclusive-use UMFUS licensees or, as another option from among others, preclude UMFUS from accessing the band.[7]

Elefante Group reiterates in Section II why the 26 GHz Band is an essential SBCS Band. It was selected by Elefante Group after a comprehensive review of spectrum between 17.0-43.5 GHz as the best candidate for downlinks from stratospheric platform stations ("STRAPS") to fixed ground-based user terminals ("UTs"). If there is to be an SBCS in this country, providing high-capacity, low-latency solutions to help accelerate widespread next-generation networks, Internet of Things ("IoT") capabilities, and other innovative services and applications, Elefante Group submits that co-primary access to the 26 GHz Band is a key element to facilitating that outcome.

In Section III, Elefante Group goes on to discuss why, in contrast, access to the 26 GHz Band for the mobile industry is not a key enabler for the deployment of 5G services within the commercial mobile industry for ground-based deployments, or a band necessary for international

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5 47 U.S.C. § 151.

6 *Third NPRM* at ¶¶ 79-91.

7 *Id.* at ¶¶ 79-91.

harmonization of 5G spectrum bands. This is because of the large amounts of spectrum already made available for UMFUS – including 24.25-24.45 and 24.75-25.25 GHz (collectively, the "24 GHz Band") as well as 27.5-28.35 GHz (the "28 GHz Band") – and the more than four additional gigahertz of spectrum still under consideration for UMFUS in this proceeding. Other purported benefits of making this spectrum available for exclusive-use UMFUS are exaggerated, Elefante Group respectfully submits.

Elefante Group, supported by the attached compatibility analyses conducted by Lockheed Martin,[8] demonstrates in Section IV that the introduction of UMFUS into the 26 GHz Band would raise very serious compatibility issues for incumbents and new services such as SBCS. Elefante Group examines why the studies concerning the compatibility of International Mobile Telecommunications ("IMT") with other services that have been performed in connection with Agenda Item 1.13 for WRC-19 fall short of describing the true potential impact of introducing UMFUS into the 26 GHz Band. As Elefante Group observes, these studies (the "ITU Studies")[9] are limited to a single use case for IMT which is particularly benign as a potential interferer in comparison with the full range of operational options available to UMFUS operators, such as higher power, broader configurations and antenna characteristics, types of service applications and resulting configurations, and other parameters which would adversely affect compatibility. The ITU Studies also make unwarranted assumptions, such as ubiquitous dense urban clutter loss and time-variant factors which mask the true potential for harmful interference to the Fixed Service ("FS"), Aeronautical Mobile Service ("AMS"), Earth Exploration Satellite Service ("EESS"), Space Research Service ("SRS"), and SBCS applications in localized settings.

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8 *See* Attachments A-C.

9 *See* studies attached to Annex 3 to Document 5-1/406-E, Chairman, Task Group 5/1, "REPORT ON THE FIFTH MEETING OF TASK GROUP 5/1" (June 11, 2018).

Nonetheless, even the ITU Studies begin to reveal the potential for incompatibility without specific regulatory constraints on UMFUS.

In response, the analyses of Elefante Group and Lockheed Martin correct for these unwarranted assumptions and demonstrate how, simply by using permitted UMFUS power levels rather than those lower powers examined in the ITU Studies, the potential for harmful interference to incumbents increases several-fold. Further analysis considering the various operational degrees of freedom that UMFUS operators would have would only magnify the serious concerns about the incompatibility of UMFUS operations.

Elefante Group also examines the potential for flexible mobile to share the same band with SBCS, as requested by the *Third FNPRM* with equally sobering results. While SBCS will protect against harmful interference into UMFUS base stations and user equipment by adhering to a well-established power flux density ("PFD") limit to protect ground-based services that already applies to other overhead space services in the Ka-Band, UMFUS base stations would present a significant degree of incompatibility with the deployment of SBCS UTs. Despite the indications that flexible mobile cannot operate on a compatible basis with incumbent services and SBCS, Elefante Group will continue to explore this matter, and welcomes dialogue with the commercial mobile industry, to evaluate whether practical coordination and cooperation measures exist that might sufficiently alleviate the interference threats from UMFUS.

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UMFUS licenses would make it unlikely that advanced SBCS systems capable of serving both urban and rural areas with high-throughput, wide-area solutions would be launched. As a result, many of the benefits that SBCS offers may never be achieved. Rather, Elefante Group submits that its wholesale vision for SBCS laid out fully in its *Petition* is the right one to make this new, essential service a reality, and to do so in a way that is truly compatible with incumbent operations.

Finally, in Section VI, Elefante Group discusses why, procedurally, the Commission should consolidate consideration of the *Petition* and adoption of SBCS rules in all of the SBCS Bands with the evaluation of future uses of the 26 GHz Band in this proceeding. As Elefante Group explains, this likely would require a new Further Notice of Proposed Rulemaking (unless the Commission believes the *Third FNPRM* can be clarified so as to obviate the need for such a Further Notice). Taking this step will not only accelerate the adoption of an SBCS regulatory framework, it will help facilitate a timely deployment of next-generation communications and IoT solutions to a larger portion of the American public by operators in all spectrum bands. As such, consolidation of the *Petition* with this rulemaking will enable the Commission to meet its obligations under Elefante Group's Section 7 request, included in the *Petition*, whereby Elefante Group sought the institution of a rulemaking within one year of the filing of the *Petition*.[10]

II. THE 26 GHz BAND IS UNIQUELY SUITED TO SBCS OPERATIONS

A. Elefante Group Has Proposed That the 26 GHz Band Be Made Available for SBCS Downlinks from STRAPS to UTs

Elefante Group, a United States corporation founded in 2015 and headquartered in Denver, Colorado, aspires to be the world leader in persistent, low latency stratospheric-based

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10 *See Petition* at 106-107 (requesting procedural treatment of the *Petition* as a "new technology and service" under Section 7 of the Act, 47 U.S.C. § 157).

communications, sensing, and infrastructure. Elefante Group has been collaborating with Lockheed Martin for over two and a half years and is leveraging Lockheed Martin's many decades of expertise with lighter-than-air ("LTA") platforms, sensing, and communications systems. As a result, Elefante Group is ready to build, test, and, beginning in 2022, commercially deploy stratospheric radio communications solutions that will serve both urban and rural areas. Toward that objective, on May 31, 2018, Elefante Group filed the *Petition* seeking rules to enable transformative SBCS in this country.[11] Elefante Group seeks access for SBCS to the SBCS Bands.[12]

SBCS radio stations, generically referred to as STRAPS,[13] would operate at nominally fixed locations between 18 and 26 km.[14] Elefante Group's LTA STRAPS would station keep at approximately 65,000 ft. (less than 20 km) altitude and support high-capacity duplex communications – 1 Tbps in each direction between fixed UTs on the ground.[15] These

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11 *See generally Petition*; *Petition Public Notice*. A copy of the *Petition* was submitted into the record of this proceeding simultaneously with its filing. Letter of Edward A. Yorkgitis, Jr., Counsel to Elefante Group, Inc., to Marlene Dortch, Secretary, FCC, GN Docket Nos. 17-183, 14-177, IB Docket No. 17-95, WT Docket No. 10-112, File No. SAT-LOA-20161115-00117 (May 31, 2018).

12 The 21.5-23.6, 25.25-27.50, 71-76, and 81-86 GHz bands will individually be referred to herein, respectively, as the "22-23 GHz Band," "26 GHz Band," "70 GHz Band," and "80 GHz Band."

13 Elefante Group uses the term STRAPS to apply to any stratospheric airborne platform radio station that meets the definition proposed in the *Petition* deployed by a SBCS operator, which could include not just LTA deployments but, for example, stations on fixed-wing platforms as well.

14 *Petition* at 86.

15 *Id.* at 3. Under Elefante Group's conception, connections between UTs would be switched by the STRAPS' payload and use the 22-23 and 26 GHz Bands. SBCS also will be capable of similar high-capacity links between UTs and fixed gateway stations. In these cases, under Elefante Group's proposal, any feeder links between STRAPS and the ground-based terrestrial network would be in the 70 and 80 GHz Bands (collectively, the "70/80 GHz Bands"). *See id.* at 81-85.

communications solutions, including 4G and 5G backhaul (enabling both buildout in rural areas and "urban deserts" as well as densification in well-served urban areas), enterprise Wide Area Networks ("WANs"), IoT enablement, and residential broadband services will benefit residents and small businesses as well as the communications, government, enterprise, and institutional sectors.

As described in the *Petition*, SBCS will be capable of delivering solutions over a 70 km radius – defining a platform coverage area of 15,400 km^2 (6,000 mi^2) – on day one of deployment.[16] As a result, SBCS solutions would be able to bypass the many infrastructure deployment problems that plague and delay ground-based buildouts, sometimes for many years after rollout begins.[17] For this reason, using 5G-compatible technologies, timely deployment of Elefante Group's SBCS systems beginning in the next four years will accelerate next-generation deployments in this country,[18] as well as service numerous other national objectives, including bridging the digital divide in both rural areas and "urban deserts," supporting the maintenance and restoration of communications during and following natural disasters, and creating thousands of American jobs.[19]

B. Elefante Group Extensively Studied Potential Spectrum Bands before Proposing Use of the 26 GHz Band by STRAPS for Links between UTs and STRAPS

Following many months of analysis in 2017 and early 2018, including numerous compatibility studies – over twenty-five of which were appended to the *Petition* and Elefante

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16 *Id.* at 3.

17 *Id.* at 27.

18 *See* Reply Comments of Elefante Group, Inc., RM-11809, GN Docket No. 14-177, at 16-19 (Aug. 15, 2018) ("*Elefante Group Petition Reply Comments*").

19 *See Petition* at 3.

Group's Reply Comments on the *Petition*[20] – and considering numerous technical and service factors, Elefante Group and Lockheed Martin evaluated the range between 17.0-43.5 GHz and identified the 22-23 GHz Band and 26 GHz Band as the best candidate spectrum for uplinks and downlinks, respectively, for deployment of SBCS-UT links in the United States at capacities that would allow SBCS to deliver its expected benefits.[21] This spectrum was identified as optimal from a technical performance perspective and based on compatibility with current allocations and incumbent uses.

The threshold consideration in identifying suitable spectrum to support deployment of SBCS was ensuring that 1 Tbps aggregate UT performance in each direction over the STRAPS coverage area would be satisfied *in encumbered spectrum and in an efficient manner*. As detailed in the *Petition*, Elefante Group and Lockheed Martin concluded that, even with a high degree of frequency reuse and spectrum compatibility built in as part of the design, in order to achieve 1 Tbps, the amount of spectrum used to permit flexible spectrum access management would need to be greater in encumbered spectrum *than in unencumbered spectrum*.[22] For Elefante Group and Lockheed Martin, compatibility required incumbent users to have the ability to modify and grow their systems within the shared spectrum while SBCS systems could achieve a reasonable penetration of deployment to meet market demand and provide a high level of

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20 *See id.* at Appendices; *Elefante Group Petition Reply Comments* at Exhibits.

21 *See Petition* at 77-79.

22 To offset the encumbered nature of the spectrum, Elefante Group's design will require: (1) more channels than the minimum theoretically required to achieve 1 Tbps to provide service in localized portions within a coverage area where compatibility prevents some channels from being used; (2) flexibility to temporarily adjust the channels being used across a service area to prevent transient harmful interference that would otherwise occur; and (3) guard band spectrum (within the SBCS system) for protection of adjacent and nearby bands from out-of-band emissions. *See id.* at 56.

service that would meet anticipated performance requirements.[23] Based on analyses of compatibility of SBCS with different categories of incumbent users throughout the 17.0-43.5 GHz range,[24] Elefante Group and Lockheed Martin determined that 4.35 gigahertz in total, including guard bands between 450 megahertz channels in the 22-23 and 26 GHz Bands, will be necessary to achieve the 1 Tbps goal.[25]

As noted above, to the extent feasible, Elefante Group and Lockheed Martin focused their efforts on bands that already have primary or co-primary fixed service allocations and in which fixed service has been licensed, since SBCS is best described as a fixed service, as its ground terminals are fixed and its platform is maintained around a nominal fixed point.[26] Examining the bands between 17 and 43.5 GHz, considering both uplink and downlink operation, bands were eliminated based on incumbent uses. Some were allocated to safety of life applications (*e.g.*, air traffic radar). Some were allocated to incompatible technical approaches or authorization

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[23] *Id.* at 60-61.

[24] Keeping apertures smaller than 45 cm while maintaining the gain necessary to support uplink and downlink of highly spectrally efficient waveforms set a practical minimum for spectrum at around 17 GHz. Keeping weather losses low enough for practical UTs and power amplifiers to maintain reasonable availability at desired rates set a practical maximum for spectrum below 50 GHz. *See id.* at 66.

[25] Capacity considerations to serve the target product markets require a minimum channel bandwidth. Elefante Group intends to support high channel rates for 4G and 5G backhaul and enterprise WANs. To achieve 1 Tbps over a large contiguous coverage area using a beam laydown pattern with the allocated spectrum broken into colors and allowing reuse of colors 130-180 times, the necessary maximum data that can be supported within a single beam are set and dictate the 450 megahertz bandwidth of the colors allocable to the beams for which Elefante Group and Lockheed Martin have designed the Elefante Group SBCS system. *See id.* at 59-60. Elefante Group and Lockheed Martin have determined that a minimum of six to eight colors (three to four bands with polarization diversity) are necessary to prevent inter-beam interference from restricting use of highly spectrally efficiency waveforms. This minimum number of colors is also necessary to avoid using colors that would harmfully interfere with or receive un-mitigatable interference from other services and for periodic STRAPS servicing, which requires handover of services between airships without interruption of service. *Id.*

[26] *Id.* at 61.

schemes, for example, UMFUS licenses set to be auctioned for exclusive licensing.[27] Some were allocated to the Fixed-Satellite Service ("FSS"), including through non-geostationary orbiting ("NGSO") satellite rulemaking, which pose extremely complicated compatibility challenges. By this process – identifying contiguous bands with the highest potential for compatible uplink and downlink operations that are close enough in frequency for single-aperture UTs and as low in frequency as possible to maximize weather availability and service area – Elefante Group and Lockheed Martin were able to settle on the proposed bands for UT operation.[28]

In addition, when selecting spectrum for SBCS, Elefante Group and Lockheed Martin ruled out the prospect of aggregating bands over a wide range. Keeping uplink and downlink bands sufficiently close, within approximately 5 to 6 gigahertz, is of particular importance for STRAPS' communications payloads. Any larger range would likely require two separate antennas on each STRAPS's payload. Doubling the number of antennas, one for uplink and one for downlink, would have large negative space, weight, and power ("SWaP") implications, requiring bigger and more expensive STRAPS. Therefore, the nearby 22-23 GHz and 26 GHz Bands are an ideal balance of required spectrum to support 1 Tbps of bi-directional capacity with reasonable SWaP and cost. A single aperture for UTs, which similarly requires both the uplink and downlink frequencies to be within a range of approximately 5 to 6 gigahertz, also lowers costs, increases ease of installation, and allows acceptable standards for mounting.

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[27] Geographic area auctions of spectrum to UMFUS present no basis for coordination with SBCS on a co-primary basis and the technical realities of having to provide protection to UMFUS without mutual coordination rights would prevent effective SBCS to the product markets Elefante Group plans to serve. *See generally infra* Section V. As explained below, in the 26 GHz Band, where UMFUS has not yet been introduced, Elefante Group is open to exploring whether rules of the road can be implemented at the start that allow flexible mobile operations to access the band on a co-primary basis with SBCS. *Elefante Group Petition Reply Comments* at 29-32.

[28] *Petition* at 55-77.

C. No Feasible Alternatives Exist to the 26 GHz Band for SBCS Downlinks

Elefante Group proposes the 26 GHz Band for SBCS downlinks from STRAPS to UTs in the *Petition*.[29] After excluding other bands for downlinks because of incompatibility of incumbents – whether because of co-band passive services, in-alignment events from large NGSO constellations, or existing UMFUS allocations where licenses would be awarded exclusively through competitive bidding – Elefante Group and Lockheed Martin tentatively concluded that the 26 GHz Band would be best suited for SBCS.[30] The 26 GHz Band is close enough to the proposed 22-23 GHz uplink Band to: (1) allow for use of a single antenna for uplinks and downlinks on the STRAPS; (2) create an appropriately-sized UT for residential installation; (3) have atmospheric attenuation low enough to practically design for high availability; and (4) be large enough to be allocated into four or more 450 megahertz bandwidth channels. 450 megahertz channels with greater than 4.5 bps/Hz efficiency permit over 2 Gbps per beam and a sufficient number of beams per the Elefante Group system design to provide over 1 Tbps capacity over a large coverage area. Elefante Group and Lockheed Martin engaged in detailed and in-depth compatibility studies and consideration of any mitigation that might be required to protect incumbents in the band.[31]

A few other notes on band selection are in order, given that WRC-19 Agenda Item 1.14 is examining 38-39.5 GHz and the full 24.25-27.5 GHz band for high altitude platform stations ("HAPS"). The 38.0-39.5 GHz band paired with either of the 21-22 GHz or 25-26 GHz Bands would not be practical for SBCS. Apart from necessitating two antennas on the airship (with the

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29 *Petition* at 4.

30 *Id.* at 77-79.

31 *Id.*

associated negative SWaP implications), the 38.0-39.5 GHz band provides only 1.5 gigahertz of spectrum, which is not enough for SBCS to meet the 1 Tbps target (in encumbered spectrum) in either direction. Moreover, this band is separated by more than 5 gigahertz from the 22-23 GHz Band, which Elefante Group has proposed for SBCS uplinks.[32] The poorer atmospheric propagation at this higher band in lieu of, say, the 26 GHz Band, renders more tenuous service availability over a 70 km radius area.[33] Plainly stated, SBCS operating in higher bands would require more link budget to overcome the increased propagation loss, driving cost, complexity, and even more mass into the airborne payload and terminals to cover the same size area at a comparable level of availability.[34] These factors make 38.0-39.5 GHz, paired with Ka-Band spectrum, unsuitable as part of a 1 Tbps SBCS spectrum.

Although it is under consideration internationally for HAPS, Elefante Group did not propose 24.25-25.25 as a SBCS Band in the *Petition* for several reasons. First, the 24.25-24.45 and 24.75-25.25 GHz bands had already been designated within the United States to UMFUS for exclusive licensing. The ability of UMFUS to compatibly coexist with other services, such as

32 *See id.* at 55.

33 *See id.* at 56-61. For the same availability target, a higher frequency system requires more power and/or margin to overcome the increased weather loss, driving cost, complexity, and mass into the airborne payload and terminals. *Id.* at 58. SBCS links necessarily have much longer path lengths through weather than anticipated ground-based mobile and fixed links in the mmW bands. The absolute value of weather loss at higher mmW frequencies is higher and the design impact to maintain margin for the same weather availability for SBCS systems is higher than for shorter-range ground-based mobile and fixed links.

34 SBCS geometry necessarily requires that links to UTs further from the STRAPS will be at longer range and lower elevation, so providing similar quality of service at the edge of coverage reasonably comparable to that at the center requires equipment on STRAPS and UTs to overcome both increased range loss and frequency-dependent weather losses through lower elevation paths. *Id.* at 59.

SBCS, is fraught with several challenges.[35] Second, there is no ITU Region 2 or U.S. allocation for fixed service in the 24.45-24.75 GHz band, and the Radionavigation allocation in the 24.45-24.65 GHz band appears to be the intended target for both airborne radar and ground radar applications (creating greater compatibility challenges with SBCS). Third, the isolated 100 megahertz spectrum over 24.65-24.75 is insufficient to accommodate the frequency color re-use bandwidth necessary to support the envisioned 1 Tbps service and the desired maximum rate in a beam.

D. Elefante Group Is Designing Its SBCS Systems to Operate on a Compatible Basis with Incumbent Uses in the 26 GHz Band

In the *Third FNPRM*, the Commission appropriately cautioned that, with respect to operations in the 26 GHz Band, "[a]ny exploration of private sector opportunities in the [26 GHz] band must . . . address the potential for spectrum sharing and compatibility among diverse participants."[36] These participants include Federal fixed service, AMS (Airborne-to-Ground), Inter-Satellite Service ("ISS"), EESS, SRS, and Radio Astronomy Service ("RAS") operators.[37] Elefante Group and Lockheed Martin have addressed the potential for spectrum sharing and compatibility in the SBCS Bands with these stakeholders and are engaged in discussions with many of them.[38] In designing trade-offs, consideration consistently was given to allow sharing to minimize impact to incumbent users. To test the success of the design, Elefante Group and Lockheed Martin have undertaken extensive studies and compatibility analyses to address

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35 UMFUS incompatibility with SBCS and incumbent services in the 26 GHz Band is considered in detail in Section IV, *infra*, as well as Attachments A-C appended hereto.

36 *Third FNPRM* at ¶ 79.

37 47 C.F.R. § 2.106.

38 Analyses with respect to the 26 GHz Band were detailed in Appendices I-M, P-S, and U to the *Petition*, with the first five examining the compatibility of SBCS when operating in the downlink mode.

sharing and compatibility with incumbents in the 26 GHz Band, including multiple analyses appended to the *Petition*.[39]

The compatibility studies indicate that, through the regulatory limits proposed in Section IX of the *Petition*, combined with coordination where required and, in certain instances, mitigation, spectrum sharing can protect existing users, allow incumbent user growth, and permit deployment of SBCS systems, including competitive systems, within STRAPS' service areas, including in the 26 GHz Band.[40] Based on these analyses, Elefante Group has continued to further integrate the goal of compatibility with incumbent operators in the 26 GHz Band (and other bands of interest) throughout the design process of the contemplated Elefante Group SBCS system.

In all analyses for a first-step bounding analysis of the Elefante Group system as interferer, the worst-case geometry and operating conditions for UTs and STRAPS[41] were utilized. In addition, each study sought to identify the worst-case geometry between the incumbent user and the SBCS system as a starting point for the static scenario.[42] Such worst-case geometries and operating conditions were analyzed regardless of the probability of the worst-case scenario arising. Where the proposed limits for SBCS operations did not ensure compatibility with a static interference protection criterion, Lockheed Martin's analysis proceeded to consider statistical analysis methods to evaluate compliance with statistical

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39 *Id.*

40 *Id. See Petition* at 85-103.

41 For the worst-case operating conditions in the downlink direction, the studies assumed the STRAPS were transmitting at a level equal to the maximum PFD limit as authorized for satellite downlinks into the fixed services, and that multiple STRAPS downlink channels were operating simultaneously to ensure that the victim bandwidth was fully occupied. *Petition* at 68, n.87. STRAPS were assumed to operate in the same polarization as the victim receiver. *Id.*

42 *Id.* at 68.

interference protection criteria for each service or to evaluate the likelihood of harmful interference.[43] This conservative approach was pursued given the objective of enabling SBCS to operate in encumbered spectrum as a co-primary service on a truly compatible basis.

In the *Petition*, Elefante Group and Lockheed Martin examined SBCS access to the 26 GHz Band for STRAPS downlinks as a fixed service on a co-primary basis with current primary incumbents.[44] Compatibility studies were conducted to evaluate the spectrum sharing capabilities between SBCS (using the Elefante Group reference design) and existing Federal incumbent uses: AMS Airborne-to-Ground Links, ISS return links, EESS and SRS downlinks, and RAS.[45] While a study was not completed regarding Federal fixed links, Elefante Group has proposed that an elevation-dependent PFD limit used by satellites and described in Section 25.208(c) of the Commission's rules be adopted by SBCS downlinks in the 26 GHz Band to afford the same protection the fixed service enjoys from other overhead services when co-primary in nearby spectrum bands.[46] There are no current non-Federal incumbent uses.[47]

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[43] In some cases, the interference protection criteria included percentages of time in which the interference threshold would be exceeded. *Id.* at 68, n.88. Nonetheless, Lockheed Martin and Elefante Group examined the worst-case static scenario first. Note that, in the compatibility analyses attached to these comments, Lockheed Martin approached issues more toward a worst-case approach so as to best capture localized circumstances where harmful interference does occur, rather than the statistical approaches embraced at the outset by others typically used when analyzing compatibility between IMT and incumbent services.

[44] *Id.* at 74-77.

[45] *Id.* at Appendices I-M.

[46] *See* 47 C.F.R. § 25.208(c).

[47] *Third FNPRM* at ¶ 75.

Appendices I through L of the *Petition* demonstrate the high degree of compatibility of STRAPS-to-UT downlinks with incumbent Federal users of the 26 GHz Band.[48] With respect to Federal AMS Airborne-to-Ground links in the 25.25-27.50 GHz band, Lockheed Martin's analysis showed a minimal likelihood of harmful interference and recommended no mitigation.[49] Regarding compatibility of STRAPS downlinks with Federal ISS Data Relay Satellite ("DRS") return links (low-earth orbit to DRS geo-stationary orbit), the analysis showed that the DRS I/N protection criterion is met by STRAPS-to-UT downlinks with greater than 33 dB of margin.[50] Regarding the potential for STRAPS downlink interference into EESS (Space-to-Earth) links operating in the 25.5–27.0 GHz band, the analysis found that the EESS interference threshold criterion was met for all placements of STRAPS and no mitigation was required.[51] With respect to potential harmful interference to SRS (Space-to-Earth) services in the 25.5–27.0 GHz band, the analysis found that, for a given SRS mission, if required, STRAPS can easily be placed to ensure that SRS I/N protection criteria are met without cognizably compromising its coverage.[52]

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48 *Petition* at Appendices I-L. Lockheed Martin also examined the compatibility of STRAPS downlink out-of-band emissions with RAS in the 23.6-24.0 GHz band (separated by 1.25 gigahertz from the proposed STRAPS downlink band). The study results show the protection criteria were easily satisfied and compatibility was achievable. *See Petition* at Appendix M; *see also Petition* at 77.

49 *See id.* at 75-76; Appendix I.

50 *See id*. at 76; Appendix J.

51 *See id*; Appendix K.

52 *See id*. at 76-77; Appendix L.

III. BY CONTRAST, BECAUSE THE COMMISSION HAS MADE AND CONTINUES TO MAKE SUBSTANTIAL STRIDES IN MAKING mmW SPECTRUM AVAILABLE FOR FLEXIBLE MOBILE AND FIXED USE, THERE IS NO COMPELLING REASON TO MAKE THE 26 GHz BAND AVAILABLE FOR UMFUS

The *Third FNPRM* asks for comment on the possibility of making the 26 GHz Band available for flexible mobile use or UMFUS.[53] The Commission also asks whether, in order to facilitate the deployment of stratospheric platform services, "UMFUS should therefore not be authorized in the 26 GHz band."[54] For the reasons discussed in this Section, Elefante Group submits that the answer to this last question is a clear "yes," unless it can be demonstrated that UMFUS can operate compatibly with SBCS (and other services) in the same spectrum so as not to jeopardize the deployment of SBCS.[55]

Elefante Group does not contest the importance of making adequate amounts of mmW spectrum available for flexible mobile use and, in fact, has a vested interest in the success of next-generation mobile networks, particularly as one of its primary business cases is to provide 4G and 5G backhaul to the providers of such services. Nonetheless, any consideration of whether to make this band (or any other band) available for flexible mobile use should take into account other spectrum that has been made available for, or is already being considered for, flexible mobile use; whether the band truly presents unique opportunities for flexible mobile use; whether the band presents a unique opportunity for other services; and whether flexible mobile operations can share with the incumbent uses. Section II demonstrated the unique nature of the 26 GHz Band for SBCS downlinks. Section IV will discuss in detail whether UMFUS can share

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53 *See Third FNPRM* at ¶¶ 75-91.

54 *Id.* at ¶ 87.

55 As discussed herein, based on the extensive analysis performed to date, Elefante Group and Lockheed Martin are unable to conclude that UMFUS has this ability.

the 26 GHz Band with Federal incumbent users. This Section will review the other spectrum that has been made available and is being considered for flexible mobile use and, more particularly, whether the 26 GHz Band is essential for flexible mobile use.

As a threshold matter, there has been no showing by the United States mobile industry that there is a need for the 26 GHz Band in light of other spectrum access decisions favoring flexible mobile use that have been made as well as those otherwise under consideration. For example, the Commission already has designated or is considering for designation more than ten gigahertz of mmW spectrum for UMFUS in the *Spectrum Frontiers* proceeding. In the First and Second Report and Orders in this proceeding, 5.55 gigahertz of mmW spectrum was made available for UMFUS − all but 600 megahertz of it on an exclusive licensing basis − in the 24.25-24.45, 24.75-25.25, 27.50-28.35, 37-40 GHz,[56] and 47.2-48.2 GHz bands.[57] To the best of Elefante Group's knowledge, this is far more than any other country has made available for flexible mobile use. Furthermore, for comparison purposes, the Commission had assigned only a total 715 megahertz of spectrum for mobile use below the mmW bands, less than 15% of the amount of new mmW spectrum made available for flexible mobile use.[58] Notably, the 715 megahertz includes several hundred megahertz of spectrum that has not yet been deployed, or is

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[56] The 37.0-37.6 GHz band will be made available on a non-exclusive basis for flexible mobile use. *See Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, *et al.*, GN Docket No. 14-177, *et al.*, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014, at ¶¶ 101-122 (2016) ("*First Spectrum Frontiers Order*" or "*First Spectrum Frontiers FNPRM*," as applicable).

[57] *See First Spectrum Frontiers Order* at ¶¶ 19-122; *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, *et al.*, GN Docket No. 14-177, *et al.*, Second Further Notice of Proposed Rulemaking, Order on Reconsideration, and Memorandum Opinion and Order, 32 FCC Rcd 10988, at ¶¶ 15-59 (2017) ("*Second Spectrum Frontiers Order*").

[58] *See Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, WT Docket No. 17-69, Twentieth Report, 32 FCC Rcd 8968, at ¶ 39, Table II.E.1 (2017) ("*Twentieth Spectrum Report*").

only at the beginning states of deployment, including 600 MHz, Advanced Wireless Service ("AWS")-3, Broadband Radio Service, and Educational Broadband Service spectrum.

It also is worth noting that, because of inherent propagation characteristics, mmW spectrum is far more likely that low- and mid-band spectrum to be deployed in denser radio network architectures with greater frequency reuse. This means that the spectral density inherently will be far higher in mmW bands than deployments in lower bands, creating much higher network capacities. Consequently, a simplistic comparison of available mmW spectrum for flexible mobile to the 715 megahertz of spectrum made available below 3 GHz understates just how much more effective spectrum capacity has been made available for mobile use in the mmW bands. In other words, the mmW allocations that have been made thus far are materially more impactful toward satisfying mobile industry needs than the derived ratio of 7.7:1 would suggest (5,500 megahertz to 715 megahertz). Any additional mmW spectrum would exacerbate the impact relative to the simplistic ratio even more.

Moreover, setting aside the 26 GHz Band at issue, the Commission currently has under consideration for UMFUS in this proceeding another 4.3 gigahertz in the 31.8-33.4, 42.0-42.5, and 50.4-52.6 GHz bands for UMFUS in this proceeding by virtue of the July 2016 *Further Notice* and June 2018 *Third FNPRM*.[59] These proposals have the support of the commercial industry.[60] Moreover, the commercial mobile advocates urge the Commission to make the

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[59] *See First Spectrum Frontiers FNPRM* at ¶¶ 386-403, 418-423; *Third FNPRM* at ¶¶ 47-57; *see also* Comments of CTIA, GN Docket No. 14-177, *et al.*, at 6-8 (Jan. 23, 2018).

[60] *See* Comments of CTIA, GN Docket No. 14-177, *et al.*, at 6-8 (Jan. 23, 2018) (advocating for the designation of the 31.8-33.4, 42.0-42.5, and 50.4-52.6 GHz bands for flexible terrestrial use) ("*January 2018 CTIA Comments*"); Comments of T-Mobile USA, Inc., GN Docket No. 14-177, *et al.*, at 11 (Jan. 23, 2018) (same) ("*January 2018 T-Mobile Comments*"); Comments of AT&T Services, Inc., GN Docket No. 14-177, *et al.*, at 4-5 (Jan. 23, 2018) (same).

remaining Local Multipoint Distribution Service spectrum available for UMFUS, yet another 450 megahertz of spectrum (namely, the 29.10-29.25 and 31.0-31.3 GHz bands).[61]

Indeed, sufficient mmW spectrum already has been made available for flexible mobile use to cause Commissioner Michael O'Rielly to state during the Commission's Open Meeting in June 2018 that consideration of spectrum caps is no longer needed – and to do so is a "charade" – whether before or after UMFUS auctions.[62] Significantly, while the Commissioner mentions that consideration of the 26 GHz Band and "other bands that have been teed up, like 32 and 50 GHz," and the 42.0-42.5 GHz band (which he did not mention) might be icing on the cake, his view is that there are already "abundant opportunities for those seeking high-band licenses" is clear.[63] Moreover, he notes that those desiring mmW spectrum also have access to unlicensed spectrum, presumably referring to the fourteen gigahertz of spectrum between 57-71 GHz reserved for such use terrestrially. In other words, no matter how the Commission slices it, not only is there plenty of mmW spectrum that has been made available thus far for flexible mobile use, but more is coming (even apart from any 26 GHz Band designation for flexible mobile). As a result, Elefante Group respectfully requests that the Commission consider whether putting the 26 GHz Band on the auction block for a small group of large providers to acquire[64] serves the

61 *See, e.g.*, January 2018 CTIA Comments at 2, 5-6.

62 *See Third FNPRM*, Statement of Commissioner Michael O'Rielly, Approve in Part, Concur in Part, at 2.

63 *Id.* While in the *Second Spectrum Frontiers Order*, and again in the Memorandum Opinion and Order accompanying the *Third FNPRM*, the Commission declined to make any part of the 57-71 GHz band available for licensed mobile use, *see Second Spectrum Frontiers Order* at ¶¶ 75-87; *Third FNPRM* at ¶¶ 37-46, Commissioner O'Rielly appears to be underscoring that unlicensed spectrum may be a valuable resource for commercial mobile carriers to access spectrum for next-generation applications.

64 Verizon, AT&T, Sprint, and T-Mobile hold approximately 76% of all spectrum, as measured on a MHz-POPs basis. *See Twentieth Spectrum Report* at ¶ 40. In addition, DISH

public interest better than ensuring that spectrum is available for the development of competitive SBCS providers.

The Commission inquires whether the designation of the 26 GHz Band for mobile would be advantageous for purposes of achieving international harmonization.[65] Elefante Group acknowledges that international harmonization can be important for creating the economies of scale that bring down equipment costs. And it is clear that a number of countries are looking at all or parts of the 26 GHz Band for 5G purposes. On the other hand, harmonization of spectrum does not require one-to-one alignment of spectrum. Through tuning range compatibility, spectrum bands adjacent to or nearby each other in different jurisdictions allow for harmonization, economies of scale, or international roaming as well as identical spectrum. The availability of the 24 and 28 GHz Bands in the United States for next-generation ground-based networks, as a result of tuning range compatibility, already ensures harmonization with equipment deployed in other countries in part or all of the 24.25-27.50 GHz range.

Notably, the Commission itself plainly acknowledges in the *Third FNPRM* that the tuning range of equipment will include at least all of the 24, 26, and 28 GHz Bands.[66] The Commission recognizes, for example, that "[e]quipment manufacturers indicate that they can readily integrate the 26 GHz band into a tuning range that includes two bands that the United States has already authorized for mobile services, the 24 GHz band (24.25-24.45 GHz and 24.75-

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holds 100% of H block and AWS-4 band spectrum as well as portions of the 600 MHz, 700 MHz, and AWS-3 band spectrum, while Comcast holds portions of the 600 MHz band spectrum. *Id.*

65 *Third FNPRM* at ¶¶ 76-77.

66 *Id.* at ¶¶ 76-78.

25.25 GHz) and the 28 GHz band (27.5-28.35 GHz)."[67] Thus, prior Commission action in this proceeding – making available the 24 and 28 GHz Bands for UMFUS – reduces any marginal benefit from allocation of the 26 GHz Band in the United States to mobile use to achieve the benefits of international harmonization. The availability of the 24 and 28 GHz Bands ensures that the United States will contribute materially to international harmonization without the need to make the 26 GHz Band available for flexible mobile: (1) to provide international roaming capability in affordable user devices and (2) to accelerate the availability of equipment in newly-authorized bands that share a tuning range with early deployed bands in the United States.[68]

Elefante Group also notes that the ITU Task Group 5/1 study of IMT is examining spectrum within the full 24.25-33.4 GHz band for the same reason that equipment may be tunable across this entire range. Within that range, in addition to the 24 and 28 GHz Bands already designated for UMFUS, there is another 2.05 gigahertz (*excluding the 26 GHz Band*) in this range that the commercial mobile industry advocates be made available for UMFUS-type operations: 29.10-29.25, 31.0-31.3, and 31.8-33.4 GHz.[69]

In addition to the more than ten gigahertz of mmW spectrum discussed above, it is also worth noting that several Commission, Congressional, and Administration initiatives are under way to make substantial amounts of C-Band spectrum available for flexible mobile use. In Europe, Asia, and around the world, spectrum bands between 3.4-4.2 GHz are seen as essential for the introduction of 5G services, the exact bands being a function of spectrum management

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[67] *Id.* at ¶ 77.

[68] *Id.* at ¶ 77.

[69] *See supra* pp. 20-21, notes 59, 61.

decisions in each country.[70] In the 3.55-3.70 GHz band, the Commission soon will make available as much as 70 megahertz of spectrum for priority access licenses ("PALs") on an auction basis. At the behest of the mobile industry, the Commission launched a pending rulemaking in late 2017 to modify the licensing rules for PALs to make them more attractive for mobile industry investment.[71] In July of this year, the Commission launched another rulemaking that is, among other things, looking at realigning and repurposing the 3.7-4.2 GHz band, which is currently allocated to the non-Federal FSS and fixed service, to make 100-500 megahertz of new spectrum available for flexible mobile use on an auction basis (while providing an as-yet-to-be-determined level of protection to incumbent users).[72]

It is also worth noting that the recently passed RAY BAUM'S Act requires the National Telecommunications and Information Administration ("NTIA"), by March 2020, to provide the Commission and Congress with an evaluation of the feasibility of allowing commercial wireless services, licensed or unlicensed, to share use of the frequencies between 3.10-3.55 GHz.[73] Even before passage of that legislation, NTIA, in coordination with the Department of Defense ("DOD") and other federal agencies, had announced that it would be conducting a

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70 *See* PolicyTracker, "The 4G and 5G Spectrum Guide 2017," at 60-61 (Oct. 2017), available at https://www.policytracker.com/mwg-internal/de5fs23hu73ds/progress?id=ecVdb_r-XrVbItDV-bRzzGvkR5V-MmIzsj-NGt2efKQ.

71 *See Promoting Investment in the 3550-3700 MHz Band*, *et al.*, GN Docket No. 17-1258, *et al.*, Notice of Proposed Rulemaking and Order Terminating Petitions, FCC 17-134 (Oct. 24, 2017); *see also* Petition of CTIA for Rulemaking to Amend the Commission's Rule Regarding the Citizens Broadband Radio Service in the 3550-3700 MHz Band, RM-11788 (June 16, 2017); Petition of T-Mobile USA, Inc. for Rulemaking to Maximize Deployment of 5G Technologies in the Citizens Broadband Radio Service, RM-11798 (June 19, 2017).

72 *Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, *et al.*, GN Docket No. 18-122, *et al.*, Order and Notice of Proposed Rulemaking, FCC 18-91 (July 13, 2018).

73 *See* Repack Airwaves Yielding Better Access for Users of Modern Services Act of 2018, Pub. L. No. 115-141, 132 Stat. 348 (2018).

comprehensive engineering study to assess the feasibility of repurposing the 3.45–3.55 GHz band, currently used for military radar and other federal systems, for commercial wireless uses.[74]

Below 3 GHz, other spectrum bands representing hundreds of megahertz have yet to be implemented fully or are under active consideration for commercial mobile use. These bands include the 70 megahertz of spectrum made available by the broadcast incentive auction which ended in early 2017,[75] fifty megahertz of Federal radar spectrum at 1300-1350 MHz under consideration for the spectrum pipeline,[76] and 50 megahertz of AWS-3 spectrum (auctioned in 2015) in the 1755-1780 and 2155-2180 MHz bands, which Elefante Group understands have not yet been heavily deployed.[77]

In short, the Commission has already made many times more spectrum available for commercial mobile than has been licensed and used by commercial mobile carriers to date. In the mmW bands, the so-called "high bands," the many thousands of megahertz of spectrum that will be auctioned mask the even higher increase in potential spectrum density with which carriers will be able to serve customers using this spectrum when compared to low-band spectrum. All

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[74] NTIA, "NTIA Identifies 3400-3550 MHz for Study as Potential Band for Wireless Broadband Use" (Feb. 26, 2018), available at https://www.ntia.doc.gov/blog/2018/ntia-identifies-3450-3550-mhz-study-potential-band-wireless-broadband-use.

[75] *Incentive Auction Closing and Channel Reassignment Public Notice; The Broadcast Television Incentive Auction Closes; Reverse Auction and Forward Auction Results Announced; Final Television Band Channel Assignments Announced; Post-Auction Deadlines Announced,* Public Notice, DA 17-314 (MB/WTB Apr. 13, 2017).

[76] *See* NTIA, "Sizing up Spectrum Sharing Prospects" (Nov. 17, 2016), available at https://www.ntia.doc.gov/blog/2016/sizing-spectrum-sharing-prospects (discussing the multi-agency initiative to determine the feasibility of making changes to the Federal Aviation Administration's long-range radars operating in the 1300-1350 MHz band that could include relocating them to another band).

[77] FierceWireless, "Verizon prepares for tests of new LTE equipment using AWS-3 Band 66" (Mar. 8, 2018), available at https://www.fiercewireless.com/wireless/verizon-prepares-for-tests-new-lte-equipment-using-aws-3-band-66 (noting that many AWS-3 deployments remain in trial phase).

of this has been achieved without access to the 26 GHz Band. There are no compelling reasons to make this band available for commercial mobile use as well, especially if such action will impede incumbent operators in the 26 GHz Band or preclude the deployment of other emerging services that would play a critical role in the widespread rollout of 5G, such as SBCS, because of the unique advantages the 26 GHz Band has for such new services which *can operate on a compatible basis*.

IV. ANALYSIS OF COMPATIBILITY BETWEEN MOBILE AND INCUMBENT SERVICES REVEALS CONSIDERABLE CHALLENGES ASSOCIATED WITH INTRODUCING UMFUS INTO THE 26 GHz BAND *VERSUS* INTRODUCING SBCS INTO THE BAND

The *Third FNPRM* seeks comment on the prospect of introducing flexible mobile use into all or a part of the 26 GHz Band.[78] The Commission recognizes that, because the band is already used by Federal incumbents, before the band can be considered for flexible mobile use, suitable sharing or protection arrangements with Federal incumbent operations would have to be in place.[79] The Commission also acknowledges that "Federal agencies may aspire to make heavier use of [the 26 GHz] band in the future. Any exploration of private sector opportunities in the band must therefore address the potential for spectrum sharing and compatibility among diverse participants."[80]

In Section III above, Elefante Group recounted how it explored in depth in its *Petition* the compatibility of SBCS with incumbent Federal users. In this Section, Elefante Group reviews the potential for compatible operation of mobile services in the 26 GHz Band, first addressing the ability of mobile applications to share with Federal fixed service, AMS, EESS, SRS, and

78 *Third FNPRM* at ¶¶ 75-91.

79 *Id.* at ¶ 78.

80 *Id.* ¶ 79.

ISS[81] operations. Elefante Group then examines whether flexible mobile use can be compatible with SBCS downlink operations. As the *Third FNPRM* observes, the European Conference of Postal and Telecommunications Administrators ("CEPT") noted that "[s]tudies need to take into account the compatibility with and protection of all existing services, including their future deployments, in the same and adjacent frequency bands."[82] Here, in the United States, where Elefante Group has made a pending proposal for SBCS to utilize the 26 GHz Band as well, sound public policy calls for the Commission to consider the compatibility of flexible mobile use with the proposed SBCS as well.

Elefante Group begins by assessing the work that has been done regarding compatibility in preparation for WRC-19.[83] Initially, there is still disagreement over the correct parameters to be used for such studies. In any event, Elefante Group's and Lockheed Martin's assessment of those ITU Studies requires certain corrections to ensure the analyses address realistic localized conditions. Moreover, the ITU Studies, as a whole, present a relatively benign IMT use case from an interference perspective for analysis – a broadband access link with restricted downtilt. Nonetheless, even study of the limited use case reveals concerns with the potential use of the band by flexible mobile applications within the United States.

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81 There is also a co-primary non-Federal allocation in the band for ISS. *See* 47 C.F.R. § 2.106.

82 *Third FNPRM* at ¶ 75, n.250 (quoting Draft CEPT Brief on WRC-19 Agenda Item 1.13, Budapest, Hungary, at 2 (Jan. 11, 2018).

83 While the Sixth Meeting of ITU Task Group 5/1 concluded on August 29, 2018, at the time Elefante Group and Lockheed Martin were evaluating compatibility of IMT, reviewing ITU Studies, and preparing these comments, the Report of the Sixth Meeting was not yet available. Consequently, the results of Fifth Meeting, which concluded on May 11, 2018, have been used for the basis of the discussion herein and in the attached compatibility analyses. Elefante Group intends that any relevant updates to the Attachments and discussion herein as a result of the Sixth meeting of Task Group 5/1 will be provided in a future filing.

To complement its examination of the ITU Studies, the attached analyses conducted by Lockheed Martin for Elefante Group building on the ITU Studies, take some initial steps to incorporate the flexibility in mobile operations as permitted under UMFUS rules applicable in other bands near the 26 GHz Band.[84] The attached analyses shed further light on the compatibility of mobile use of the band within the United States, given existing Federal operations and other new services being considered, specifically SBCS. As explained below, even when allowing only for the higher power permissible under the UMFUS rules (compared to the lower power used in the IMT scenario in the ITU Studies), *flexible mobile use would present significant challenges both for incumbent Federal users as well as SBCS.*

As explained below, UMFUS presumably will have more flexible base station antenna characteristics than depicted in the ITU Studies (and in the attached Lockheed Martin assessment) and could be used in architectures and applications more detrimental than the single scenario looked at in the ITU Studies. Also, cumulative effects of multiple base stations are relevant because UMFUS configurations, especially in more urban or densely populated or trafficked areas, will realistically involve a relatively high density of base stations. In short, there is good reason to believe that further analysis beyond using UMFUS EIRP levels in the IMT base station use case would reveal the compatibility problems are even greater than discussed in the current results. Accordingly, the Commission should proceed with caution and consider excluding or placing serious restrictions on any use of the 26 GHz Band by flexible mobile operators.[85]

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[84] *See* Attachments A-C.

[85] For its part, despite the foregoing, Elefante Group will continue to consider whether there are ways in which flexible mobile uses could compatibly use the same band as SBCS downlinks.

A. The Results of the ITU Studies, Even without Appropriate Modifications, Reveal Concerns that Ground-Based Mobile Services Are Not Compatible with Incumbent Services in the 26 GHz Band

As a threshold matter, analyzing the compatibility of flexible mobile with other services to yield meaningful and reliable results requires a basic and shared understanding of the mobile system characteristics. In the international process of examining the 26 GHz Band, for example, this has not been the case thus far. ITU Studies demonstrate that administrations are not in agreement that compatibility studies are using comparable inputs[86]:

> Some administrations were of the opinion that there is no coherence between studies carried out in terms of assumptions, criteria, parameters, and other data elements used in the studies at this stage. Consequently, should these incoherence[s] not be resolved, it would make it difficult to compare the results in order to obtain general conclusions of studies carried out in a given frequency band.[87]

Similarly, there was concern that variables affecting probabilities were creating issues with comparing the results at this point:

> Some administrations are of the view that a number of parameters received from the expert group are stochastic in nature and are presented as typical or average values with or without distribution function. The usage of such parameters in sharing and compatibility studies depending on methodology applied for the study will have a result of stochastic nature (*e.g.*, depend of % of a time and % of a location). In order to compare and understand the results of different studies description of statistical property of the

[86] *See, e.g.*, Document 5-1/287-E, Annex 3 to Task Group 5/1 Chairman's Report, "SHARING AND COMPATIBILITY STUDIES OF IMT SYSTEMS IN THE 24.25 27.5 GHZ FREQUENCY RANGE" (Feb. 1, 2018) ("*Document 5-1/287-E*"); Document 5-1/406-E, Annex 3 to Task Group 5/1 Chairman's Report, "SHARING AND COMPATIBILITY STUDIES OF IMT SYSTEMS IN THE 24.25 27.5 GHZ FREQUENCY RANGE" (May 22, 2018); Document 5-1/TEMP/122-E, "SHARING AND COMPATIBILITY STUDIES OF IMT SYSTEMS IN THE 24.25 27.5 GHZ FREQUENCY RANGE" (Aug. 23, 2018).

[87] *Document 5-1/287-E* at 3.

> results (*e.g.*, % of a time, % of a location) of a study shall be provided.[88]

Further, Task Group 5/1 notes that the studies have "not been completed or agreed to yet" and "it would be premature to arrive at views or conclusions on this work."[89]

Leaving aside the lack of consensus regarding IMT parameters to be used to assess compatibility in the 26 GHz Band with other uses, as discussed below, the tentative conclusions reached within the 24.25-27.50 GHz studies hardly indicate compatibility between incumbent services within the United States and mobile services as modeled by the ITU Studies. As Elefante Group explains further in this section, when UMFUS-style EIRP parameters are used, based on the rules adopted for the 24 and 28 GHz Bands, the results are even less promising.[90] Further studies would look at different (more liberal) antenna characteristics that UMFUS rules in other mmW bands permit (but the ITU Studies do not examine) as well as a broader array of use cases that UMFUS rules would give licensees the freedom to implement.[91]

1. The ITU Studies indicate that detailed coordination by mobile operators will be required to permit coexistence in the 26 GHz Band

The *Third FNPRM* notes that the ITU Task Group 5/1 has been evaluating the potential for sharing and compatibility between mobile and fixed service, EESS, SRS, FSS, and ISS in the 26 GHz Band.[92] Elefante Group focuses its comments on the results of the ITU Studies concerning fixed service, EESS, and SRS, and briefly comments on other ITU Studies.

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88 *Id.*

89 *Id.*

90 *See infra* Section IV.A.2.b.

91 Elefante Group recognizes that, assuming for the sake of argument that the Commission were to allow UMFUS in 26 GHz Band, it could choose to do so subject to certain restrictions not applicable in other UMFUS bands.

92 *Third FNPRM* at ¶ 81.

With regard to the conventional ground-based fixed service, the summary conclusions of the seven ITU Studies Elefante Group and Lockheed Martin reviewed collectively found that the separation distances required between IMT base stations and fixed service receivers to prevent co-channel harmful interference were between 0.5 and 70 km.[93] These studies applied a wide range of methodologies, including variations on deterministic and Monte Carlo analysis. Although the summary comments optimistically concluded that "[f]or both point-to-point and point-to-multipoint, coexistence between IMT-2020 and fixed service receivers can be achieved taking into account local specifics, frequency separation and deployment scenarios,"[94] every study either directly concluded that detailed coordination would be required on a case-by-case basis with IMT base stations and, in some cases, even IMT mobile stations or user equipment to permit coexistence, or demonstrated the need for large required separation distances (without speculation on implications for compatibility). Table 1 on the next page summarizes the results:[95]

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93 Attachment 5 to Annex 3 to Document 5-1/406-E, "SHARING AND COMPATIBILITY OF FS AND IMT OPERATING IN THE 24.25-27.5 GHz FREQUENCY RANGE," at 145 (May 22, 2018).

94 *Id.* at 147.

95 Page numbers for study conclusions as documented in table.

Study (page #)	Conclusion or Results
A (36)	"Unless having a large frequency or distance separation of the IMT 2020 system and the FS system a kind of coordination procedure will be needed for interference-free deployment of both systems in the 26 GHz band."
B (68)	"Based on these results, if the deployment of FL [fixed links] is dense and in a similar urban environment, it is expected that co-channel sharing is unlikely to be possible without the introduction of some form of detailed coordination approach. The feasibility of such a coordination approach is a separate matter that would require further consideration."
C (79)	19.4-33.5 km separation for worst-case alignment of FS and base station beams. 1 km when base station projects beam toward FS and FS 30 degrees in azimuth away from base station.
D (86)	10.3% of simulated cases showed base station harmful interference into FS, requiring 4.2 km separation. 12.4% of simulated cases showed user equipment harmful interference into FS, requiring 1.4 km separation.
E (104)	29% chance of harmful interference when FS located inside a 1 km^2 cluster of base stations.
F (114)	34 km separation between base station and 50-meter high FS hub, 24 km separation to 20-meter high FS customer premises equipment.
G (144)	2.6-52.2 km separation for worst-case alignment of FS and base station beams (depending on height). 0-4.7 km separation when base station aimed toward FS aimed 180 degrees away (depending on height).

Table 1: Summary of Results of the ITU Studies Regarding Separation between IMT Base Stations and FS Links to Avoid Harmful Interference

With regard to EESS and SRS earth stations, the ITU work undertakes Monte Carlo and deterministic studies that use blanket clutter models. Section 3.2 of Recommendation ITU-R P.2108 ("Recommendation ITU-R P.2108"), which is used throughout almost every ITU IMT Study, provides a single statistical approximation for losses to clutter (buildings, foliage, etc.) as a function of distance.[96] Tellingly, the same model is applied identically in both urban and suburban environments, despite the lower building heights and greater instances with fFuline-of-sight in the latter. The assumption of dense urban clutter loss in all cases leads to an understatement of harmful interference potential from the IMT systems where local conditions do not reflect that blanket assumption. The studies found separation distances between Earth Stations and IMT base stations between 0.2 and 1.7 km to be adequate to protect the incumbents against harmful interference, whereas studies that used clutter models developed specifically for the examined sites found separation distances between 3 and 7 km necessary.[97] Moreover, the non-site specific studies for SRS Earth Stations found the need for separation distances between 0.8 and 2 km, whereas studies that examined specific sites found separation distances between 23.8 and 92 km necessary.[98] The U.S. study found that the coordination distances necessary to prevent IMT from causing harmful interference to EESS/SRS Earth Stations, when considering and specifically modeling the clutter environment around White Sands, NM, are 52 km for SRS and 7 km for EESS.[99]

Elefante Group submits that these studies, helpful as they are, may well understate the real impact of IMT systems on EESS and SRS. Importantly, both the EESS and SRS results in the ITU Studies, which conduct both site-specific and non-specific analyses, highlight the tendency for generalized studies to overlook key, real-life effects (*e.g.*, local topography that

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96 *See* Recommendation ITU-R P.2108, Prediction of clutter loss, § 3.2 (Feb. 2017) ("*Recommendation ITU-R P.2108*").

97 *See* Attachment 1 to Annex 3 to Document 5-1/406-E, "SHARING AND COMPATIBILITY OF EESS/SRS AND IMT OPERATING IN THE 24.25-27.5 GHz FREQUENCY RANGE, at 124 (May 22, 2018) ("*Attachment 1*").

98 *Id.* at 125.

99 *Id.* at 22.

permits dramatically higher received power from direct line-of-sight versus statistical clutter models) that require either sufficient regulation or situation-specific coordination to ensure protection.[100] As an example, the U.S. study found that blind application of the clutter model, instead of considering the actual clutter environment, would seriously underestimate the required separation distance for a specific SRS Earth Station as 19-20 km instead of 51-52 km when the actual clutter environment was used.[101]

2. The ITU Studies do not reflect real-world UMFUS operations, minimizing their ability to adequately describe local interference environments incumbents may experience

a. The ITU Studies' assumptions mask localized interference environments

The results produced so far from the ITU Studies of IMT compatibility strongly suggest that, even when multiple factors that mitigate the statistical probability of degree or duration of harmful interference are assumed, incumbent services can be protected only through regulation of IMT infrastructure deployment. However, Elefante Group submits that the studies understate the impact of IMT because many, if not most, of the factors used in the ITU Studies are only useful to assess the likelihood of interference over long durations and large coverage areas under specific assumed use cases; they do not properly represent many real-life deployments in which the local interference environment dominates. The ITU Studies also fail to examine other use cases that would be expected to result in a much higher likelihood of harmful interference. These shortcomings of the ITU Studies, ordered by their potential to understate harmful interference in real situations, are described below.

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[100] This lesson, as explained below, is equally applicable to protecting fixed services as well as other incumbent services.

[101] *Attachment 1* at Study A, 24.

Clutter losses: Elefante Group appreciates that clutter can reduce the potential for harmful interference with nearby systems due to transmission losses over and between structures, especially in dense urban environments. However, different environments present different amounts of clutter, and some present almost no clutter at all. ITU IMT modeling for ground-based victims (fixed service and EESS/SRS) applies Section 3.2 of *Recommendation ITU-R P.2108* to assess the minimum clutter losses as a function of distance.[102] In reality, and as recognized in Section 3.1 of *Recommendation ITU-R P.2108*, these losses and their statistics are a complicated function of the height and distribution of clutter and the height of the affected transmitter and receiver.[103] But Section 3.2 makes no distinction between dense urban and suburban environments, which clearly would have markedly different characteristics in interference potential relevant to clutter.[104]

Indeed, Recommendation ITU-R P.2108 Section 3.2 is recommended only when more detailed modeling like that in Recommendation ITU-R P.1411 cannot be conducted, and the latter document delineates five different environments (urban very high-rise, urban high-rise, urban low-rise/suburban, residential, rural) each with distinct propagation phenomena determining clutter loss.[105] In all cases, the height of the interfering and victim antennas relative to the clutter is critical. Although the height of base station and user equipment transmitters in

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[102] *Recommendation ITU-R P.2108* at § 3.2.

[103] *Id.* at § 3.1.

[104] For example, a transmitter with most of its line-of-sight paths blocked beyond 100 meters by tall and close-packed high-rise buildings may have a dramatically expanded field of view over suburban low-rise buildings and more diffraction over their rooftops.

[105] *Recommendation ITU-R P.1411* at § 3.2.

ITU Studies is fixed,[106] the first three environments listed above, with different clutter heights and dominant propagation effects, are treated identically in the ITU Studies. Notably, as will be discussed in more detail later, UMFUS can include many more use cases than the narrowly-defined IMT case, with transmitters over a wide range of heights and operating in residential and rural environments as well. As noted previously, the U.S. study submitted for IMT and SRS compatibility found this ubiquitous clutter model overestimated clutter loss, as one specific case, in the environment around White Sands, NM.[107]

Importantly, a statistical model does not capture real-life situations where clutter is not a significant contributor to suppress harmful interference potential. Whereas the ITU Studies' model might predict over 35 dB additional clutter loss at a 1 km range, real situations will not always have nearly that much clutter. For example, as illustrated in Figure 1, a base station serving a waterfront area can have clutter-free line-of-sight to victims across the water over near and far distances. Similarly, any topography with lower elevation between two points can significantly reduce or eliminate clutter. A base station on a hill can have unimpeded line-of-sight to potential victims on other topographic high points, between hills in the same city (as depicted) or valleys.

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106 The heights of base station and user equipment transmitters are not parameters necessarily reflected in the Recommendation ITU-R P.2801 3.2 model, which only accepts frequency, distance, and location probability.

107 *Attachment 1* at 125.

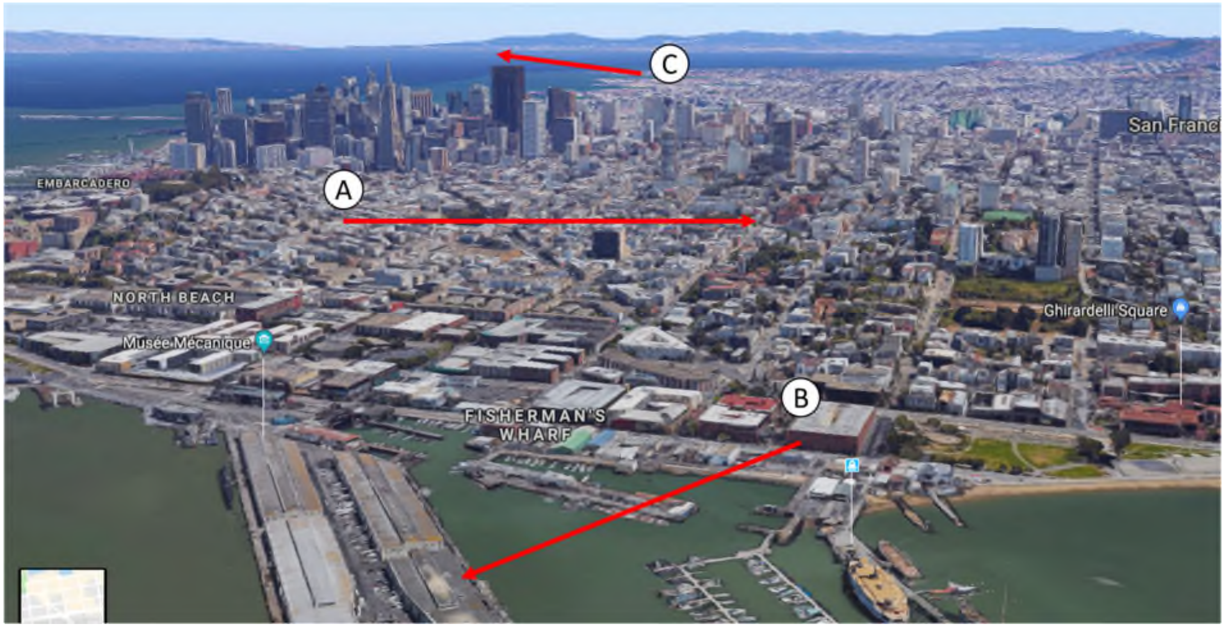

Figure 1: Realistic interference paths with no or significantly reduced clutter loss. A) line-of-sight from street corners on one hill to another hill. B) hotspot on waterfront with line-of-sight across water to nearby locations. C) sites near waterfront with line-of-sight across several kilometers of water.

By presuming a high level of clutter uniformly, the ITU Studies underestimate the potential for harmful interference by introducing mobile operations in many common situations by tens of dB and, therefore, fail to provide insight into realistic situations that will require further regulation or coordination of flexible mobile deployment to protect incumbent services.

<u>Beam pointing probability distribution</u>: The ITU Studies employ Monte Carlo analyses that assume beams will be aimed to different locations within the 120-degree sector they are covering based on a probability distribution for user equipment locations.[108] The distribution used dramatically (and, in many cases, unrealistically, as discussed below) favors communications paths directed toward user equipment centered in the sector at about 30 meters

108 Annex 1 to Document 5-1/406-E, "SYSTEM PARAMETERS AND PROPAGATION MODELS TO BE USED IN SHARING AND COMPATIBILITY STUDIES," at 9 (May 18, 2018) ("*Annex 1*").

range, as shown in Figure 2, which present much lower interference potential towards victims outside the planned cell coverage than beams aimed closer to the edge of the cell.

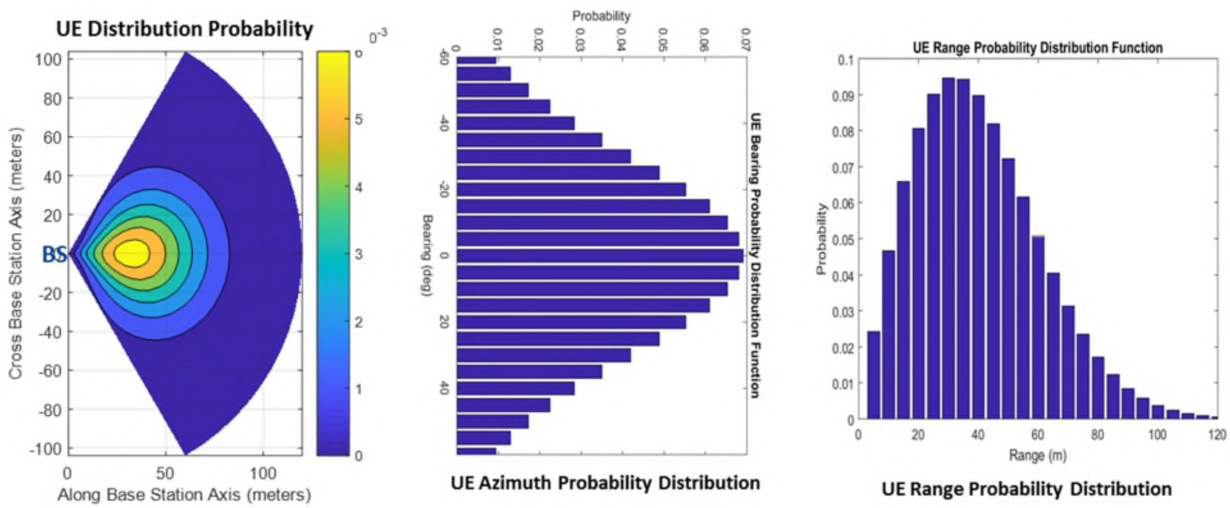

Figure 2: Assumed probability distribution of user equipment locations significantly favors base station beams aimed at lower elevations where harmful interference effects on other services are reduced.

The studies relying on this distribution assumption weight compatibility results toward lower interference than other probability distributions would. Unfortunately, the ITU Studies' underlying choice of user equipment distribution is questionable. In some deployments, a single base station will be responsible for a hotspot area, like a park or square, where users are more evenly distributed over a broader arc, rather than in the center of the range. In other flexible mobile deployments, users will typically be clustered, for example in coffee shops or seating areas, but not necessarily centered in the base station sector. As a further example, if three 120-degree sector base stations are collocated at one site to provide complete 360-degree coverage, the azimuth distribution concentrated at the center of each sector certainly is incorrect and would be expected to be roughly evenly weighted in azimuth across the full, combined 360 degrees. Moreover, as discussed below, many proposed uses for UMFUS depart dramatically from the narrow distribution for user equipment and the assumed base station position in the ITU Studies.

Importantly, even if the distribution of base station beam pointing was more inclusively described, it would not capture how beamforming will vary with time. In some cases, user equipment is nearly continuously in motion, as in vehicle or pedestrian traffic. In others, the beams might be expected to remain fixed on user equipment positions for potentially hours, as when a user is sitting in an outdoor café or on the deck of a residence. In some use cases, user equipment is not mobile at all, but rather an essentially fixed wireless link from a small cell to a node at a residence intended as a substitute for fiber, in which case the beam and whatever harmful interference it produces could be effectively fixed and continuous.

Without consideration of the many different types of beam distributions possible, the ITU Studies miss realistic harmful interference situations that would require coordination and underestimate the separation distances necessary to support compatible operation or to trigger coordination.

Time-variant factors: Several time-variant factors are included in the ITU Studies' statistical analyses, such as the Network Loading Factor,[109] TDD Activity Factor, and base station power division towards user equipment.[110] Such factors may be applicable for aggregate statistical arguments. But they may misrepresent the harmful interference into a ground victim receiver from a local IMT base station communicating with a single stationary user equipment or another base station for long durations, as further described below.

Network Loading Factor: In the Monte Carlo analyses contained in the ITU Studies, it is assumed that only some fraction of mobile network base stations are active at a given

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109 *Id.* at 3.

110 *See* Recommendation ITU-R M.2101, Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies (Feb. 2017) ("*Recommendation ITU-R M.2101*").

moment in time, and that activity is a binary state where stations are either on, and supporting the assumed number of user equipment per station, or off, and supporting no user equipment.[111] In reality, a continuum of activity may be seen across the network and activity will change geographically throughout the day as populations shift from office to residence (among other factors). Thus, some areas will experience higher than average activity during certain times of day and lower activity during other times, with different localized interference effects on other services. These effects will not be captured when they are effectively averaged over long periods of time through Monte Carlo assumptions. Use of a Network Loading Factor in Monte Carlo analyses may be appropriate for victims with large geographic coverage across multiple base station coverage areas, such as satellite beams. However, receivers for other ground-based services such as fixed service and AMS could be impacted much more severely because the duration of harmful interference would be a function of the activity of only one or more nearby IMT base stations that could be transmitting for undefined durations towards the victim receiver.

<u>Base station power division</u>: The ITU Studies assume that every base station forms beams toward the same number of user equipment at a given instance of time, and that the base station will divide power equally over these beams.[112] As noted for network activity, however, an IMT base station realistically will serve different numbers of user equipment at different times, even down to a single user equipment. As a result, the base station's beams will be of different powers, even to the point (per the modeling algorithm at least) where all the power is in a single beam. The interference impact to a potential other service receiver will depend on the time-domain dynamics of the IMT system and the other service's associated

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[111] *Annex 1* at 18.

[112] *See Recommendation ITU-R M.2101*, § 2.3.

waveform. As a consequence, a simplistic model of dividing up base station power to a constant number of user equipment may not be representative of impacts to the other service.

Additionally, if an IMT base station does compensate for range loss by increasing power to the user equipment farther from it, this will weight power towards higher elevation transmit beams at the edge of the base station coverage area with more potential for harmful interference to other services. The IMT user equipment probability model assumes the same transmit power to each user equipment, regardless of distance which may underrepresent the level of interference seen by other services.

TDD Activity Factor: Some ITU Studies introduce a TDD Activity Factor, where there is a duty cycle between base station and user equipment transmission over the same spectrum (or even a duty cycle between multiple base stations that would otherwise interfere with each other). Certainly, this factor reduces the average percent time of harmful interference from each source within the same frequencies, but it would be an error to assume simplistically that the potential for interference is reduced proportionately to the time the transmitter is off. Rather, the impact of interference depends on the system configuration and parameters of the interfering and victim system. If, for example, an affected victim uses a switching time longer than the fractions of a millisecond planned for 5G TDD,[113] receiving harmful interference 50% of the time will corrupt the longer packets and result in the loss of much more than the presumed 50% of the data on the link (potentially all of it). Again, such time-variant factors used in the ITU Studies may be appropriate when addressing the average likelihood of interference across large geographic areas and over long time periods. But these factors tend to overlook local

113 Lähetkangas, Eeva, *et al.*, "Achieving low latency and energy consumption by 5G TDD mode optimization," ICC'14 – W8: Workshop on 5G Technologies (2014).

interference situations and may impede the development of mitigation strategies where harmful interference does occur.

b. The narrowly-crafted ITU Studies are of limited utility for understanding how UMFUS will impact incumbents

While there have been multiple studies completed in preparation for WRC-19 looking at IMT compatibility, Elefante Group submits that they are of limited utility for considering introduction of UMFUS in the 26 GHz Band in the United States for two additional reasons beyond those discussed above. First, the ITU Studies do not address the range of possible UMFUS architectures, but have a much narrower focus and, as a result, *may dramatically underestimate compatibility concerns*. The ITU Studies address IMT-type user access links subject to considerable constraints; this service configuration not only represents merely a single possible use of flexible-mobile that the Commission might consider permitting under the broad heading of UMFUS, but it is a particularly benign configuration in terms of posing interference threats to incumbents. Second, the system parameters in the ITU Studies – such as EIRP density levels – are more narrowly constrained than those UMFUS radios could employ, such that the IMT ITU Studies, even apart from the other problems, do not fully capture the potential for harmful interference that UMFUS would present in the United States. Each of these problem areas is discussed in more detail below.

i. The possible range of UMFUS architectures will increase the potential for harmful interference to incumbents relative to the limited scenario examined in the ITU Studies

Turning to the first of these points, within IMT as defined by the ITU Task Group,[114] the user access links between user equipment and small cell base stations that have been studied are just one example of the mobile use cases that could be deployed in the 26 GHz Band under an UMFUS regime. For example, flexible mobile architectures may employ cross-links *between* small cells for network backhaul, which would function like point-to-point links. In addition, flexible mobile architectures could include cross-links from small cells to macro cell towers, also resembling conventional fixed wireless service links.

These two use cases would result in dramatically different localized interference scenarios than the one utilized in the ITU Studies. In the case of cross-links between cells, the beams would be nearly horizontal between base stations (assuming base stations are mounted at the same height) instead of tilted down to user equipment. In this configuration, the flexible mobile transmitters would project higher EIRP toward the horizon and be able to affect more distant fixed service and EESS/SRS Earth Station victims at higher interference levels. If using the same beamforming array as the ITU-studied scenario, the resultant beams would have a broader beamwidth than typically specified for fixed service in the band. Thus, the threat of harmful interference would present over a broader swath of azimuth than the studied scenario.

In the case of cross-links from small cells to macro towers, even higher elevation links likely would be introduced. This potentially increases the aggregate interference into higher elevation receivers pointed towards the ground, such as fixed wireless receivers on hills and ISS

[114] Report ITU-R M.2376-0, Technical Feasibility of IMT Bands Above 6 GHz, at 27-36 (2015) ("*Report ITU-R M.2376-0*").

space service. Both of these use cases underscore the lack of justification for using time-variant statistical assumptions to understand potential interference in localized environments, as discussed above with regard to the ITU Studies. Here, such assumptions would not be applicable because these are essentially fixed wireless backhaul links likely operated continuously or near-continuously between fixed points.

In addition to the types of cross-links just described, UMFUS, if extended to the 26 GHz Band as conceived in other bands, permits a wide variety of other applications, already seen in the various industry 28 GHz trials that are discussed below, but not analyzed in the ITU Studies. These other applications could include fixed wireless to homes in residential environments, fixed wireless point-to-multipoint backhaul, and other backhaul or small cell mesh network schemes. Indeed, there are few limits on the architectures that could be pursued under UMFUS, which in addition to the mobile service includes provisions for more conventional-type fixed service, as well as "Transportable Stations."[115] In the absence of site-based licensing or registration, Transportable Stations that might be relocated and operated anywhere would in particular present interference issues if regulation did not require prior coordination with other services.

The indiscriminate use of time-variable factors is questionable in the preliminary statistical studies without being balanced by examining scenarios where the factors are unwarranted. A key flaw in many of the ITU Studies is that they apply a sophisticated model based on the described assumptions and Monte Carlo scenarios to generate statistics about interference but fail to examine how sharing may be accomplished in specific, localized realistic worst-case interference situations. Deriving a required separation that satisfies interference protection criteria some percentage of the time (*e.g.*, 99%) is insufficient to determine

[115] 47 C.F.R. § 30.202.

compatibility or how sharing would be accomplished between co-primary systems. For example, if the statistically probable clutter loss on the interference path is 25 dB higher than the unobstructed line-of-sight case, but unobstructed line-of-sight between the interferer and victim locations cannot be ruled out until they are known, interference at a considerable range is possible and should trigger coordination to assess the potential interference in more detail. The statistical answer from a Monte Carlo study only provides (if the underlying assumptions did truly reflect the actual implementation and operation of both systems) the chances that coordination will require no compromise to either system assuming that necessary separation distances are even feasible. Even though conditions approximating the worst case are unlikely, they must be considered to understand these important implications on the regulatory framework for sharing. Below, in Section IV.B, Elefante Group, supported by further compatibility analysis by Lockheed Martin, shows the difference between worst-case interference and interference predicted at different likelihood levels using the mitigating effects in the studies. The results show a large disparity and therefore the need to establish a coordination trigger at fairly large distances.

ii. UMFUS operators will implement deployments with higher power, higher elevation angles, and other characteristics that will exacerbate the potential for harmful interference over the limited scenario examined in the ITU Studies

Now moving to the second consideration outlined at the beginning of this sub-section, as set out in the Commission's current rules for the 24 and 28 GHz Bands, UMFUS operations, if extended into the 26 GHz Band, would create greater opportunities for interference than the IMT user access links that have been studied, even ignoring the narrow scope and unwarranted blanket use of certain factors in the ITU Studies. For example, UMFUS, as currently defined in

Part 30 of the Commission's rules for the adjacent 24.25-25.25 and 27.5-28.35 GHz bands, allows for operations at higher powers than those characterized by the IMT user access links that have been studied in preparation for WRC-19.[116] Whereas in ITU Studies the base station maximum EIRP density is -4.9 dB(W/MHz),[117] UMFUS rules permit 25 dB(W/MHz),[118] which translates to a 30 dB higher potential interference level. Similarly, in the ITU Studies, the maximum user equipment EIRP is 9 dBW,[119] while UMFUS rules permit 13 dBW,[120] a 4 dB higher potential interference level.[121]

Further, in the ITU Studies, base station antennas all operate with a mechanical downtilt of 10-15 degrees and electrically steer beams from the most probable location of the user (32 meters per ITU's recommendation) to the small cell edge at 120 meters.[122] Thus, the ITU Studies emphasize horizontally-projected interference typically 8 degrees off the base station beam boresight, and never less than 2 degrees. The conclusion of compatibility in the ITU

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116 *Id.*

117 Attachment 2 On Spectrum Needs To A Liaison Statement To Task Group 5/1, "CHARACTERISTICS OF TERRESTRIAL IMT SYSTEMS FOR FREQUENCY SHARING/INTERFERENCE ANALYSES IN THE FREQUENCY RANGE BETWEEN 24.25 GHz AND 86 GHz," at Table 10 (Feb. 28, 2018) ("*Attachment 2*").

118 47 C.F.R. § 30.202(a).

119 *Attachment 2* at Table 10.

120 47 C.F.R. § 30.202(b).

121 The compatibility studies included with these comments focus on interference from base stations rather than user equipment, as the latter are lower power and lower in the clutter environment so they should, *at least individually,* pose less of an interference threat to ground receivers. Due to the wide variety of potential use cases and the potential for aggregate interference, user equipment interference should be studied, especially when the relative geometry between victim receivers and the base stations that user equipment aims beam at can be better defined.

122 Annex 1 to Document 5-1/406-E, "SYSTEM PARAMETERS AND PROPAGATION MODELS TO BE USED IN SHARING AND COMPATIBILITY STUDIES," at 9 (May 18, 2018).

Studies relies heavily on the clutter environment which is more likely under such a narrowly defined elevation angle use case because obstacles on the order of the base station height statistically reduce the chances of direct line-of-sight to victim receivers.

As illustrated in Figure 3, UMFUS, however, sets no limits on elevation angle, allowing radically different geometries with dramatically different compatibility with other services. Industry trials in the 28 GHz Band (discussed further below), using equipment intended to be tunable in the future to the adjacent 26 GHz Band, indicate links to out to 600-2000 meters.[123] At these distances, horizontally projected EIRP comes from less than 0.5 degrees off the base station beam boresight, almost as high as the peak EIRP. For distances as large as these, the base station height likely must be increased specifically to reduce the clutter loss that statistically reduces interference to victims in IMT-2020 analyses.

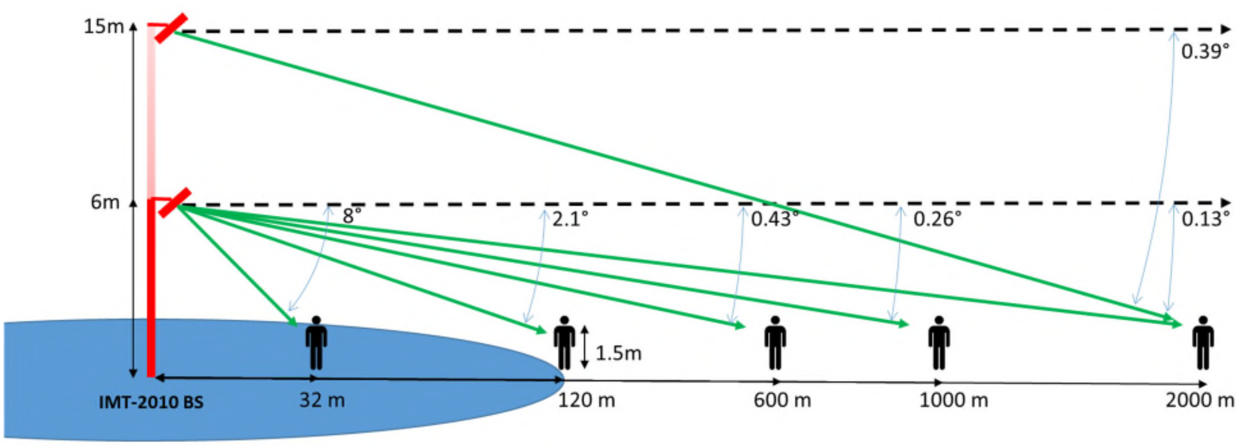

Figure 3: UMFUS, not limited to IMT-2020 geometry, can present dramatically higher EIRP toward other terrestrial victims. Larger ranges than IMT-2020 small cells present beam boresights much closer to the horizon and consequently project significantly higher EIRP in the horizontal direction. (Note, not to scale.) Higher base station antennas make little difference at range, and will necessarily have lower clutter losses.

123 The ITU Task Group 5/1 study of IMT examines the full 24.25-33.4 GHz band for this same reason.

Moreover, in the ITU Studies, base station and user equipment antenna gain and beamforming characteristics are narrowly circumscribed. In contrast, given the Commission's emphasis on flexible use that might make sense with exclusive licenses that do not have to share (except in very limited circumstances) with other services, UMFUS provides no guidelines or limits on antenna patterns.[124] For example, existing UMFUS rules would permit a transmitter with high EIRP located at high altitude using a wide beam width antenna having the potential to cause interference over a wide coverage area without the benefit of clutter loss. The only limits on field strength for UMFUS are with respect to geographical boundaries between licensed UMFUS service areas.[125] Field strength at range from IMT-2020 base stations is implicitly limited by the specified element power and beamforming assumptions.

While some might argue that higher EIRP density values than presented in the ITU Studies may not be practically realizable with current equipment, Elefante Group submits that, because they are permitted, they should form the basis of compatibility studies. Even if early 26 GHz Band UMFUS systems operated below the Commission's 24/28 GHz Band limits, were they adopted in the 26 GHz Band as well, and even assuming (which is questionable, as explained herein) that the levels of operation ensured compatibility with other incumbents and new services at present, continued compatibility as technologies and use cases evolve in the future that took full advantage of the flexibility afforded by the rules can hardly be assured. In

[124] Guidance on directional antennas is provided in 47 C.F.R. § 30.406 for the 38.6-40.0 GHz band, but not for the 24.25-25.25 or 27.50-28.35 GHz bands.

[125] 47 C.F.R. § 30.204.

addressing compatibility questions at the start, the Commission should assume that if UMFUS operators can do it, whether now or in the future, they will do it.[126]

iii. The 5G trials conducted to date reflect the operational freedom UMFUS operators will enjoy which will increase the potential for harmful interference to incumbents in the 26 GHz Band

The importance of proceeding cautiously before making any decisions about the future use of the 26 GHz Band is further illustrated by the 5G trials that the mobile industry have been undertaking. The 5G trials that have taken place, as reported publicly, bear out that carriers have in mind architectures and operational parameters that render the scenario in the ITU Studies insufficiently representative of future mobile operations in the mmW bands. Examples of applications considered for the 28 GHz UMFUS band that readily could be translated to the 26 GHz Band show that carriers intend to take full advantage of the higher powers and flexibility that the UMFUS rules permit, in contrast with the limited scenarios posited in the ITU Studies. By doing so, it is clear that carriers have in mind additional use cases that are significantly different from the limited applications studied for IMT-2020, taking advantage of a wider range of permissible technical parameters than the ITU Studies imply.

For example, Huawei and NTT DOCOMO have trialed long distance 28 GHz links to user equipment from urban towers.[127] In this use case, the 1.2 km user equipment coverage

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[126] By analogy, when testing radiofrequency equipment and devices for certification purposes and compliance with the applicable rules for the type of equipment, the Commission's rules require that worst-case operating conditions be assumed. *See, e.g.*, FCC, *Signal Boosters Basic Certification Requirements*, Doc. No. 935210, at 4 (June 18, 2018) (noting that worst-case results for occupied bandwidth comparisons and intermodulation tests must be provided for signal booster device certifications).

[127] Huawei, "Huawei and NTT DOCOMO Mark Milestone in 5G Joint Trials with Successful High-Speed and Long Distance mmWave Field Trial at Tokyo Skytree" (Dec. 7,

distance of the trial link (as depicted in Figure 4) is hardly a small cell, which is typically represented by a 120-meter coverage distance in ITU Studies. Also, with the 340-meter elevation base station well above clutter, it presents an interference situation far beyond that of a 6-meter high IMT base station serving urban hot spots.

Figure 4: Huawei trialed 28 GHz links over distances substantially larger than IMT-2020 scenario and presenting higher interference levels at larger ranges.

U.S. carriers have conducted trials of fixed wireless broadband from small cell base stations to residences in several markets in the 28 GHz Band. These cells are dramatically different than those assumed for IMT-2020. Whereas in IMT-2020, the cells have about a 120-meter radius, the trials seek 5G rates on links with up to a 600-meter range with a corresponding

2017), available at https://www.huawei.com/en/press-events/news/2017/12/NTT-DOCOMO-5G-mmWave-Field-Trial-Tokyo.

increase of cell coverage.[128] Alternatively, operators considering point-to-multipoint architectures with hubs managing spectrum reuse for fixed wireless backhaul are looking to 28 GHz,[129] with links with ranges at 20 km.[130]

Additionally, IMT-2020 makes assumptions about the density of deployment of rural and suburban small cells that do not appear consistent with many emerging deployments of small cells or 28 GHz applications in the United States and abroad which will necessitate dense base station deployments. Unlike the localized urban and suburban mobile user "hotspots" modeled for IMT, fixed wireless broadband to residential users requires ubiquitous deployment of small cells through neighborhoods.[131] Even current deployments are exceeding the ten-base-stations-per-km^2 parameter for IMT suburban hotspot density.[132] Additionally, mmW 5G connectivity to high speed cars and rail will require closely-spaced base stations along transport routes.[133]

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128 Verizon fixed wireless cells in a Houston trial were 425 meters apart, while other testing found link viability at 600 meters. *See* FierceWireless, "SRG's tests of Verizon's 28 GHz Houston network show resilience, but gigabit data speeds may be challenging in near term" (Feb. 21, 2018), available at www.fiercewireless.com/wireless/srg-s-tests-verizon-s-28-ghz-houston-network-show-resilience-but-gigabit-data-speeds-may.

129 Cambridge Broadband Networks proposes point-to-multipoint service. FierceWireless, "CBNL ready to support millimeter wave auction winners" (Aug. 2, 2018), available at www.fiercewireless.com/wireless/cbnl-ready-to-support-millimeter-wave-auction-winners.

130 *See* Cambridge Broadband Networks Website, available at www.cbnl.com/why-choose-licensed-pmp.

131 *See* Light Reading, "Charter Reveals New Details on 4G/5G Trials" (Sep. 12, 2017), available at www.lightreading.com/mobile/5g/charter-reveals-new-details-on-4g-5g-trials/d/d-id/736242.

132 Steel in the Air, "SITA Research Reveals the Real Big Game in Houston was in Small Cells" (Feb. 14, 2017), available at www.steelintheair.com/Blog/2017/02/big_game_houston-was_small_cells.html.

133 An NTT DoCoMo, AGC, and Ericson trial used base stations separated between 30 and 50 feet on alternating sides of a road. *See* Press Release, "Success with 5G Communications Using 'Vehicle Glass Mounted Antenna' for 5G Connected Car" (July 25, 2018), available at http://www.agc.com/en/news/pdf/20180725e.pdf.

Whereas in IMT-2020 the base stations operate with a 10 to 15 degree mechanical downtilt, some American carrier trials have included base stations launching beams at high elevation angles toward neighboring buildings, a radically different geometry. Figure 5 illustrates one such trial, showing a base station on a low-rise building launching beams towards windows of nearby high-rise buildings, and indicating beams directed at user equipment more than 2 km from the base station. Unlike IMT-2020, which limits interference range by specifying urban base station heights at 6 meters and below rooftops, the base station in this application would be elevated higher above clutter and able to interfere with victims at further ranges. With relatively wide beamwidths, these transmissions could project significant interference toward antennas deployed on neighboring rooftops.

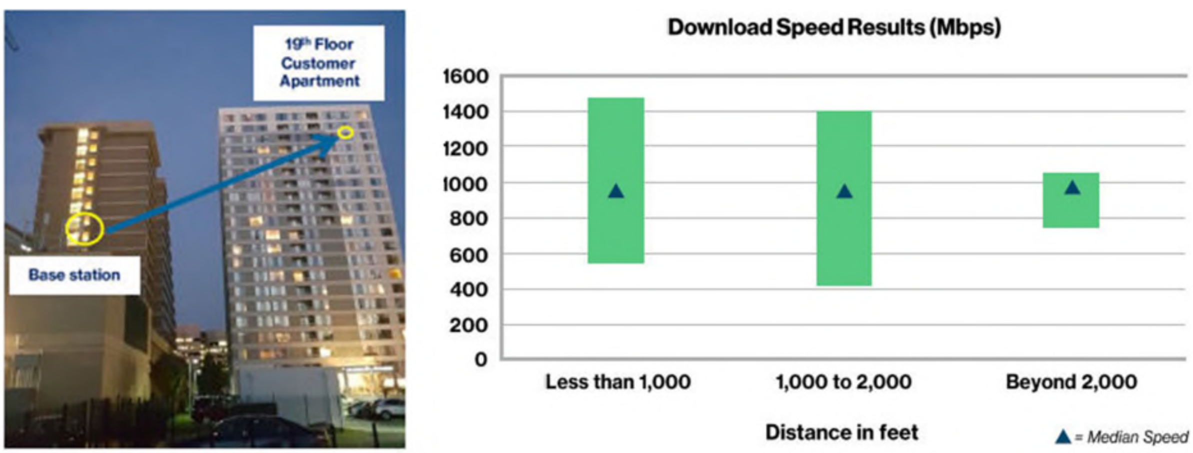

Figure 5: Verizon trials included base stations with high elevation angle beams to user equipment and small cell sizes 6 times the diameter assumed in IMT-2020.[134]

What is clear from just these few examples is that 5G cells in 28 GHz are planned to be substantially larger than the small cells examined in ITU Studies taking advantage of a variety of operational freedoms. To enable these deployments, UMFUS operators may use higher power,

134 Figure images from IEEE ComSoc, "Verizon will offer residential '5G' fixed broadband service in 2018" (Dec. 1, 2017), available at http://techblog.comsoc.org/2017/12/01/verizon-will-offer-residential-5g-fixed-broadband-service-in-2018/.

elevation angles may be shallower or even above the horizon (*e.g.*, pointed toward a high-rise building), and base stations may be more elevated above clutter than in the ITU Studies. Each of these alone will create a greater potential for harmful interference to other services. Furthermore, UMFUS may be applied to other, non-mobile user access link applications, such as broadband fixed wireless user links and fixed point-to-point and point-to-multipoint backhaul networks. In short, UMFUS likely will create more opportunities for interference to other services than the ITU Studies reveal.[135]

B. Further Analysis by Elefante Group and Lockheed Martin Identified Key Challenges for Flexible Mobile Operations Sharing with Incumbents

As discussed above, the studies that have been conducted with regard to Agenda Item 1.13 of WRC-19 not only examined a single mobile deployment scenario, but they also included a number of other deficiencies that impede examination of localized interference environments. Elefante Group and Lockheed Martin have performed further analyses building on the ITU Studies, while at the same time taking the opportunity to correct what Elefante Group submits are shortcomings, to provide a more complete picture of the potential for harmful interference to incumbent services.[136] (In the case of AMS, Elefante Group and Lockheed Martin conducted an entirely new analysis, as no such study is found within the ITU Studies.) As explained further below, and detailed in the attached analyses,[137] Elefante Group and Lockheed Martin obtained more sobering results than the ITU Studies previously suggested. Elefante Group submits this is

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135 In addition, UMFUS will be more susceptible to co-primary interferers than the IMT-2020 application, complicating coordination.

136 *See* Attachments A-C. Elefante Group and Lockheed Martin did not study the potential *harmful interference of incumbent services into flexible mobile operations*. Elefante Group presumes that the mobile community will assess this themselves. If so, Elefante Group reserves the right to comment on those compatibility studies.

137 *See id.*

a more realistic picture. In turn, these results identify some key challenges flexible mobile operators will have in sharing with incumbents in the 26 GHz Band. Further, were the analysis to expand beyond correcting the limited scenario studies used in the preparation for WRC-19 to include other use cases and the full range of operational freedoms permitted under the Commission's UMFUS rules, those challenges would likely be magnified even further.

Domestically, the 26 GHz Band is used principally for Federal government services under primary allocations, including fixed service, AMS, EESS (space-to-Earth), SRS (space-to-Earth), and ISS. Compatibility of flexible mobile use with each of these (excepting ISS) is discussed below.

1. Fixed Service

As discussed above, the existing ITU Studies, despite their shortcomings, already show a notable potential for harmful interference from IMT user access link operations into conventional, ground-based fixed service. Lockheed Martin conducted a detailed analysis of possible flexible mobile use into such fixed service, which is presented in Attachment A, appended hereto.[138] Once Lockheed Martin made the adjustments described above for clutter losses and time-variant factors such as the Network Loading Factor, base station power division, and the TDD Activity Factor, it found that harmful interference from flexible mobile base stations even for the fixed user access links scenario into fixed service receivers locally can be more severe than the ITU statistically-tempered studies suggest.[139] In short, such harmful interference is possible over large areas when line-of-sight is possible.[140] This is not overly

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138 *See* Attachment A.

139 *Id.* at A-14-A-15.

140 *Id.* at A-14.

surprising because high-gain fixed service receivers are sensitive to base station beams aimed toward them in azimuth, even with the assumed negative elevation angle of those beams in the user access link scenario (albeit without clutter).

Figure 6 illustrates the large area over which a base station pointed in azimuth towards a fixed service receiver can harmfully interfere even when utilizing the ITU IMT base station characteristics and user equipment distribution statistics.

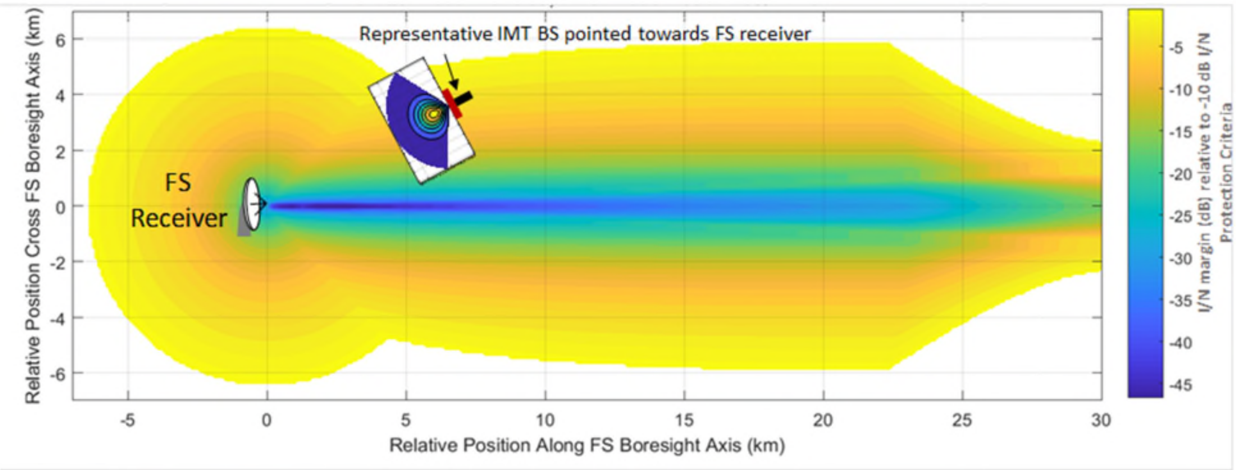

Figure 6: Base station with line-of-sight and pointed in azimuth toward FS receiver can present harmful interference over a very large area (without clutter loss).

The ITU Studies assume considerable clutter loss is always present, which has the effect of reducing the size of the harmful interference region, as illustrated in Figure 7. However, fixed service receivers will remain sensitive over a large area particularly in their boresight-pointing direction, even when clutter is present. But more importantly, many deployment scenarios would not benefit from clutter loss to the extent assumed in the ITU Studies. Moreover, multiple base stations will result in a cumulative effect of overlapping interference regions, thus further constraining fixed service future growth. The ITU Studies did not examine potential cumulative effects. However, the anticipated densities of base stations are high enough such that cumulative effects would seem inevitable in many environments.

Cumulative effects of multiple IMT base stations should be considered in perspective of the ITU stated IMT densities[141]:

- 10 base stations/sq-km for Suburban hotpots (clutter assumed)
- 30 base stations/sq-km for Dense Urban hotspots (clutter assumed)
- 1 base station/sq-km for Open Space hotspots (line-of-sight)

For example, in a suburban area, for the line-of-sight environment with a coverage area where there is negative I/N margin relative to the protection criteria of 518 sq-km represented in Figure 6, there could be as many as 518 total IMT base stations deployed within the potential harmful interference zone. Even if the actual numbers are a small fraction of these figures and understanding that only a subset of the base stations will be pointed towards the fixed service receiver, the potential for cumulative harmful interference is clear.

Similarly, for the clutter environment with a coverage area of 148 sq-km represented in Figure 7, in an urban or suburban environment, there could be as many as 1,480 to 4,440 IMT base stations deployed with corresponding overlapping potentially harmful interference areas. Therefore, although the harmful interference zone from a single IMT base station is much smaller than without clutter, the aggregate result could result in severe constraints on either or both the fixed service and mobile deployments.

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[141] Working Party 5D, "ATTACHMENT 2 ON SPECTRUM NEEDS TO A LIAISON STATEMENT TO TASK GROUP 5/1, CHARACTERISTICS OF TERRESTRIAL IMT SYSTEMS FOR FREQUENCY SHARING/INTERFERENCE ANALYSIS IN THE FREQUENCY RANGE BETWEEN 24.25 AND 86 GHZ" (Feb. 28, 2017).

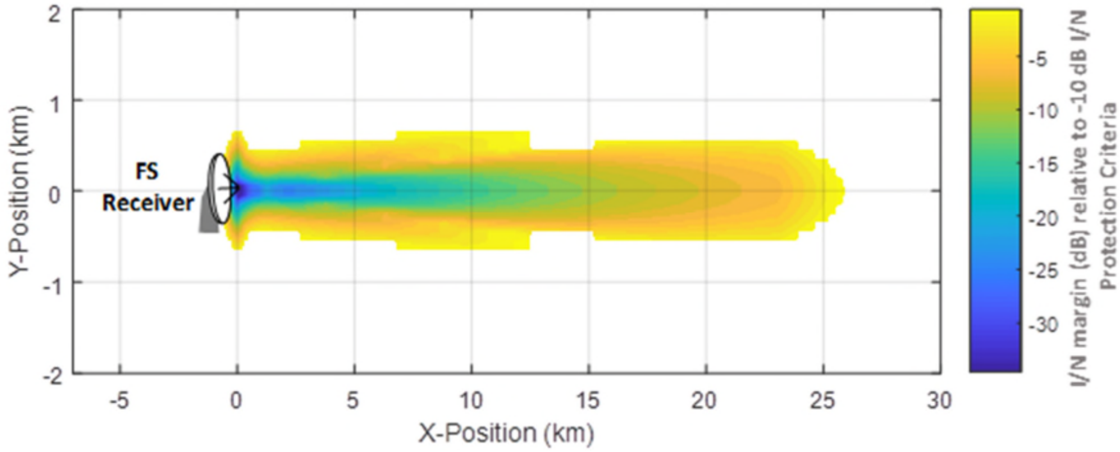

Figure 7: Models assuming clutter reduces distance where they are sensitive to base station beams but still over a large area relative to individual IMT base station coverage area.

As noted above, UMFUS operations would not be limited to the relatively benign operational scenario used in the ITU Studies. Merely an increase in transmit power alone would result in considerably more interference potential by mobile base stations. Specifically, Lockheed Martin conducted an analysis similar to that reported above with the only change being use of the maximum base station EIRP density permitted by the UMFUS rules.[142] As shown in Figure 8, even assuming the IMT-2020 base station antenna characteristics and downtilt, the ITU Studies' statistical user equipment distribution, *and including clutter loss*, the interference area is large and a 12-40 km separation distance would be required for a single base station to meet the fixed service protection criteria.[143] If clutter loss is excluded, the interference area *in all directions* would extend more than 30 km, well beyond the nominal 14-16 km horizon. This is not surprising because the UMFUS-permitted EIRP density is 30 dB higher than that assumed in the ITU IMT analyses. Were other operational freedoms permitted to UMFUS

142 *Id.* at A-13-A-14.

143 Note the very different scale of Figure 8 compared to Figures 6 and 7.

licensees considered, such as those discussed earlier in Sections IV.A.2.b.i-ii, the potential for harmful interference from UMFUS operations would only increase.

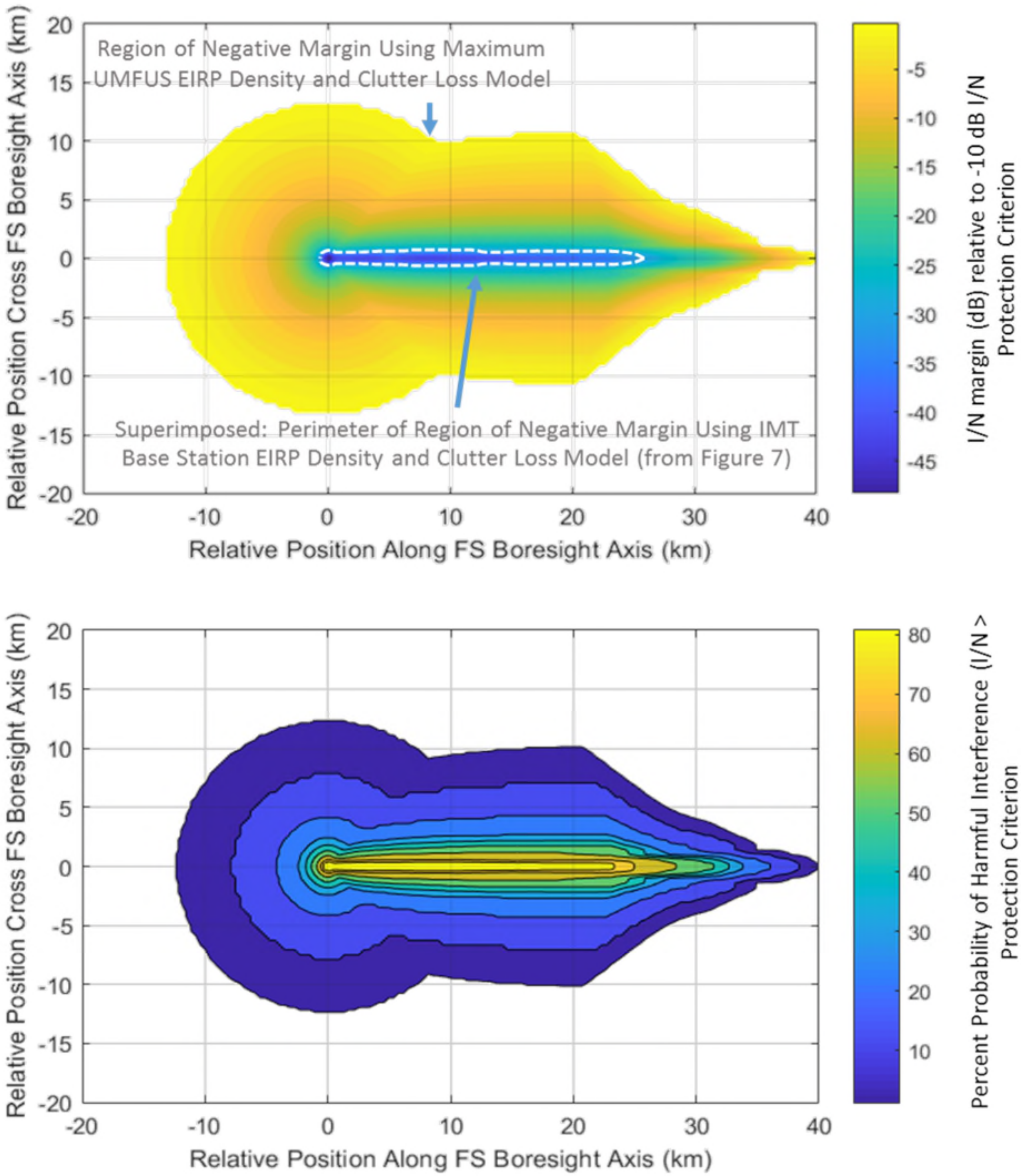

Figure 8: I/N Margin (top) showing increase in harmful interference region using UMFUS max EIRP density vs IMT EIRP density and Probability of Interference (bottom). All with assumption of dense urban clutter loss.

2. Aeronautical Mobile Service

The situation with respect to flexible mobile compatibility with AMS is similar to that of the conventional fixed service. Although there are no published ITU compatibility studies of IMT interference into AMS, Elefante Group and Lockheed Martin conducted analysis to study flexible mobile interference into AMS for the IMT deployment used in the ITU Studies, but using assumptions more representative of localized interference environments, as detailed in Attachment B, appended hereto.[144] As in the conventional fixed service scenario, Lockheed Martin first analyzed revised results using the earlier discussed corrections applied to the ITU Studies' fixed user access link architecture, and then extended the focus to consider the use of permitted UMFUS EIRP levels.[145] Other degrees of freedom permitted by UMFUS rules were not studied, but, again, they would only increase the interference potential in any given locality were they exploited.[146]

An AMS ground receiver tracks AMS airborne terminals across the sky (above a 3-degree minimum elevation angle). Harmful interference in this case to the AMS system is best quantified as percent Sky Blockage, which represents the percentage of possible pointing angles over which the interference from the base station interferer exceeds the I/N protection criteria.[147] Figure 9 illustrates the large area around the IMT base station over which the percent Sky Blockage of the AMS ground receiver is severe, even when utilizing the ITU IMT base station

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144 *See* Attachment B.

145 *See id.* at B-1.

146 *See id.* at B-14-B-15.

147 *See id.* at B-9-B-10.

characteristics and user equipment distribution statistics.[148] As reference, the percent sky subtended by the sun is approximately 0.001%[149] in contrast to the 1 to 10% Sky Blockage represented in Figure 9. As noted above, the ITU Studies' statistical methods typically assume clutter is always present, which improves results. However, clutter is inapplicable or materially less present in many localities where deployments may occur.

Moreover, where multiple flexible use mobile base stations are present within an area, the impact to Sky Blockage experienced by an AMS ground receiver would be cumulative. For example, including clutter loss, the Sky Blockage exceeds 1% out to 1.2 km in front of the IMT base station and exceeds 10% 0.5 km in front of the IMT base station, which is much larger than the small cell IMT base station coverage distance of 100-120 meters assumed in ITU Studies. Using the ITU IMT base station density of ten base stations/sq-km for suburban hotspots, this would mean that the area illustrated in the right-hand figure below could accommodate 160 such hotspots, which could significantly constrain deployment of either AMS, IMT, or both systems.

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[148] As noted previously, if user equipment is not concentrated at 32-meter range in small cells but rather further, base station transmit beams will be directed to further range and higher elevation angles. In the case of AMS, this will worsen the percent Sky Blockage results.

[149] *See id.* at B-10.

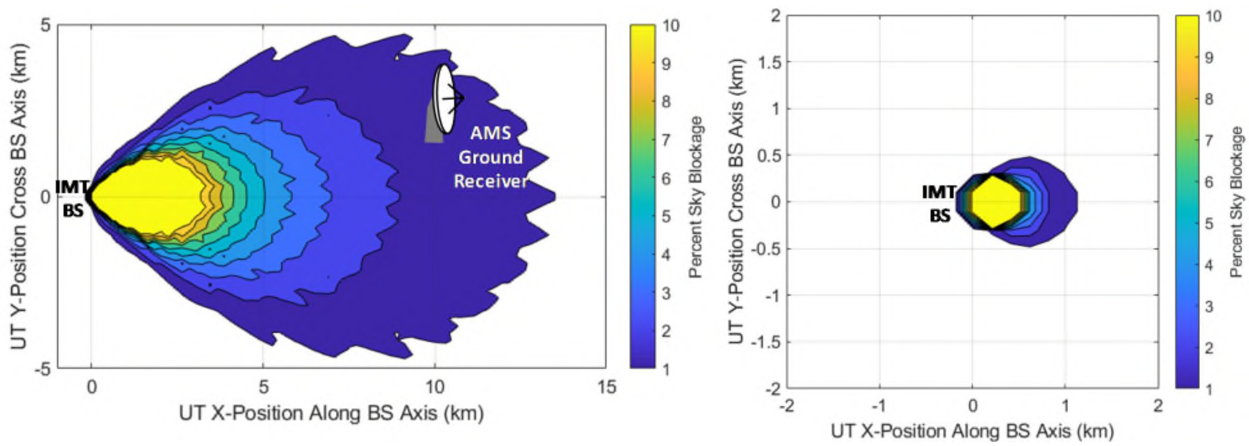

Figure 9: Percent Sky Blockage vs AMS ground location in base station frame. Left figure is assuming line-of-sight, right figure (note different scale) is with the assumption of dense urban clutter loss.

For the same reasons as in the conventional fixed service scenario, time-variant factors were not used in the Elefante Group assessment in order to better represent realistic scenarios in which the local interference environment may result in a long duration of interference into the AMS receiver from the flexible mobile deployment environment.

Using the UMFUS EIRP density of 25 dBW/MHz for the base station instead of the -5 dBW/MHz utilized in ITU Studies significantly increases the area of Sky Blockage as shown in Figure 10.[150] Again, this analysis still assumes the narrowly-defined antenna characteristics, geometry, and user equipment distribution defined for ITU Studies and as discussed above for interference into fixed wireless service. Alternative use cases and operational parameters permitted by UMFUS could dramatically increase the level and impact of interference even beyond that depicted in Figure 10.

150 Note the very different scale of Figure 10 compared to Figure 9.

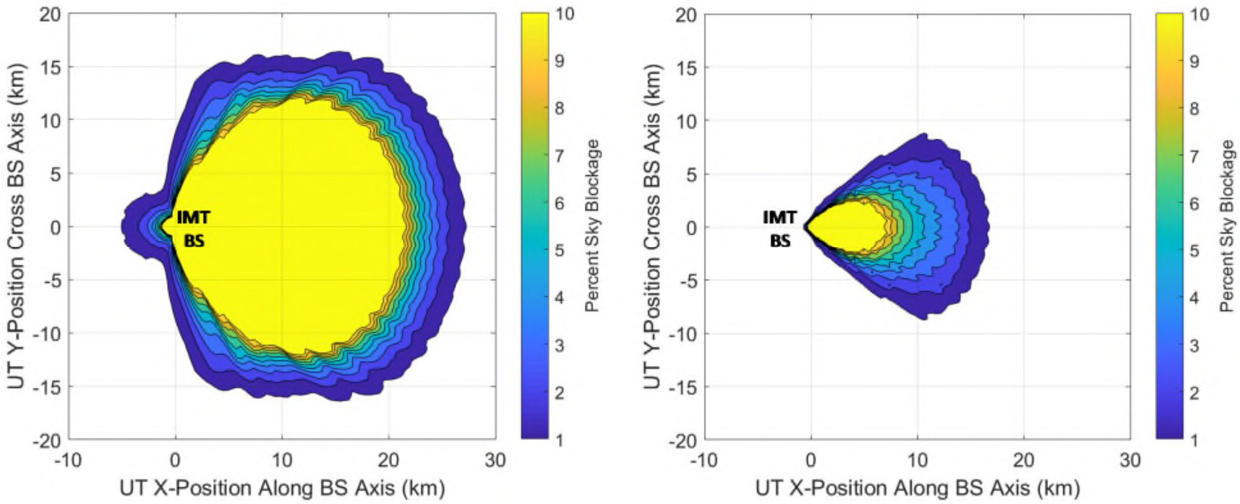

Figure 10: Percent Sky Blockage vs AMS Ground location in base station frame with UMFUS EIRP Density. Left figure is assuming line-of-sight, right figure is with the assumption of dense urban clutter loss.

3. EESS/SRS (space-to-Earth) links

As discussed earlier, the U.S. contribution to ITU Studies on Agenda Item 1.13 found that, to avoid harmful interference into the passive services, certain separation distances are required between flexible mobile base stations in the IMT-2020 fixed user access links scenario and passive receivers. Those distances were 52 km for SRS and 7 km for EESS.[151] Moreover, specific sites may have a sensitivity that will increase these numbers. If additional analyses were to be performed utilizing the increased flexibility and higher EIRP density levels allowed for UMFUS, one would expect the above separation distances required to avoid interference to increase notably. As noted, the UMFUS EIRP density limit is 30 dB higher than the values used for base stations in the ITU Studies. Each 10 dB increase extends the range of harmful

151 *Attachment 1* at 124.

interference to EESS and SRS base stations by approximately a factor of three – an *increase of twenty-seven times* for an increase of 30 dB.[152]

C. Further Analysis by Elefante Group and Lockheed Martin Demonstrates That Sharing between Mobile Use and SBCS Downlinks Is Difficult

The *Third FNPRM* seeks comment on the potential for sharing between flexible mobile use and SBCS (and other stratospheric services).[153] As discussed below, while Elefante Group continues to analyze the issue, sharing by UMFUS with SBCS, as with incumbent services, is extremely challenging and practical solutions are not self-evident. While the SBCS downlink in the 26 GHz Band that Elefante Group proposes in the *Petition* will not present a cognizable threat of harmful interference to UMFUS-type operations, given the SBCS regulatory measures proposed in the *Petition*, UMFUS deployments would, absent a significant amount of coordination, pose a material threat of such interference to SBCS UTs over a considerable distance.

1. SBCS is highly unlikely to cause harmful interference to UMFUS

SBCS will use the 26 GHz Band for downlink from STRAPS to UTs.[154] In essence, the ability of SBCS to operate compatibly with flexible mobile operations is comparable to SBCS's ability to operate compatibly with conventional fixed service, which was studied in the *Petition.*[155] Elefante Group proposed that SBCS downlinks be subject to the same PFD limits that fixed and mobile services in the Ka-Band must already be designed to accept from space

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152 The increase in the size of the interference zone would be even greater than this factor.

153 *Third FNPRM* at ¶ 87.

154 *Petition* at 4.

155 *See id.* at 69-70, 89-92, Appendix B.

services (with a similar high elevation angle geometry) − the co-primary Earth Exploration Satellite, Space Research, and Inter-Satellite services.[156]

It should be noted, however, that an appropriate PFD limit that allows SBCS to operate compatibly with flexible mobile service is not an assurance that the two services can operate in the same spectrum. For that, because compatibility is a two-way street, an evaluation of *potential mobile interference into SBCS downlinks must be undertaken.*

2. UMFUS presents a material probability of harmful interference to SBCS UTs

In contrast with the firm expectation that SBCS, as proposed, will not cause interference into UMFUS operations, UMFUS base stations and user equipment are likely to cause harmful interference into SBCS downlinks in the 26 GHz Band, even were measures taken specifically to mitigate interference a SBCS UT receives from (and transmits to) other ground antennas. Motivated both by compatibility with other services and to maximize shared use of spectrum between SBCS STRAPS serving the same areas, as explained in the *Petition*,[157] the proposed SBCS UT antenna gain pattern specification[158] calls for gain to roll-off to a back-lobe floor level at the same angle off boresight as the minimum elevation for links. This back-lobe floor of -20 dBi at 15 degrees off boresight and beyond is 29 dB lower than the Part 101 rules for the minimum gain Category A antenna permitted at 15 degrees for conventional fixed service antennas at 25.25 GHz. Thus, the receive gain of UT antennas in the horizontal plane is

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156 *Id.* at 94 (referencing the international PFD limits in Article 21). This limit also applies to the Fixed Satellite Services as well as these other services in nearby Ka-Bands with fixed and mobile allocations. *See* 47 C.F.R. § 25.208(c) (imposing a PFD limit applicable to GSO space stations in the 17.7-19.7, 22.55-23.55 GHz, or 24.45-24.75 GHz bands, or for an NGSO space station in the 22.55-23.55 or 24.45-24.75 GHz bands).

157 *Petition* at 79-81.

158 *See id.* at Appendix A.

essentially uniform in all azimuth directions, regardless of where in the STRAPS' service area the UT is deployed.[159] The combination of high elevation pointing-angles of UT receivers (15 degrees or above and, in most cases, likely to be 25 degrees or more) and low horizontally presented gain is still insufficient protection against expected UMFUS interference.

Lockheed Martin conducted a detailed analysis for UMFUS base station interference into SBCS UTs, which is presented in Attachment C, appended hereto.[160] As shown in Figure 11, a single mobile base station having the limited characteristics and user equipment distribution statistics assumed in the ITU Studies will harmfully interfere with a SBCS consumer UT up to 1.2 km away in a line-of-sight situation.[161] Clutter loss, if present, can reduce that distance to ~0.4 km, but, as noted above, this degree of clutter loss should not be assumed to apply in all deployment scenarios. Further, as in the fixed service case, the effect of multiple base stations deployed in sufficiently close proximity to the SBCS UT would be cumulative, increasing the potential for and degree of harmful interference.

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[159] The Commission's observation that SBCS UTs near the periphery of the STRAPS coverage area with lower elevations might require larger separation distances from mobile operations than higher elevation links near the center of the coverage area generally is true based on gain roll-off from the STRAPS beam peak. However, variation in separation distances from SBCS UTs are negligible across the service area because the UT antennas pointed towards the STRAPS are specified to roll-off sufficiently that the gain specified for backlobe is presented in all azimuthal angles, even when their elevation angle is at its minimum at the edge of the service area.

[160] *See* Attachment C. None of the ITU Studies in preparation for WRC-19 look at IMT access link interference into stratospheric (*i.e.*, HAPS in the case of Agenda Item 1.14) ground stations.

[161] *See id.* at C-12. As in the cases of UMFUS harmful interference into conventional fixed service and AMS, in the real world, time-variant factors may not help in mitigating interference into the SBCS UT. For this reason, Lockheed Martin did not include time-variant factors in its assessment.

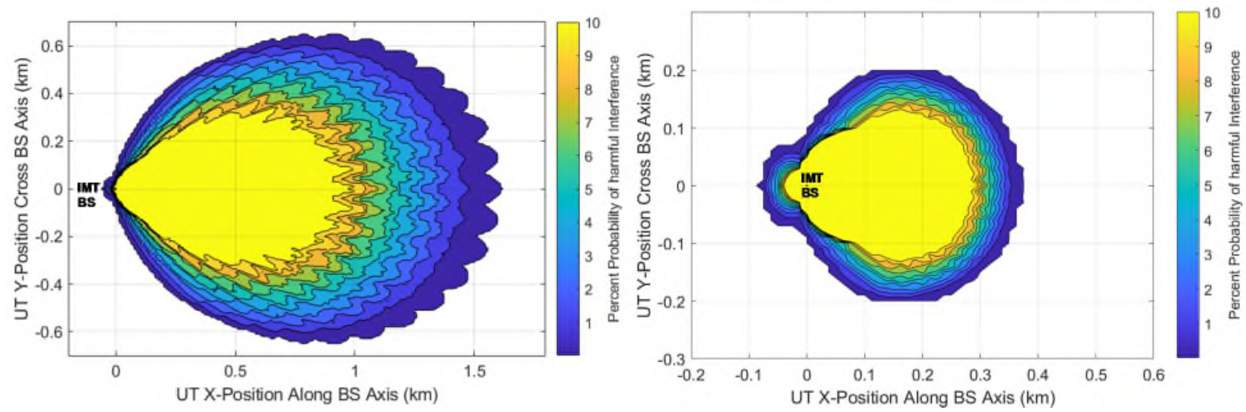

Figure 11: Percent probability of interference from IMT base station into SBCS consumer UT in worst case with line-of-sight (left) and with clutter loss (right). Contours depict probability based on ITU probability distribution for user equipment locations in base station reference.

Using the UMFUS base station EIRP density, which is 30 dB higher than -5 dBW/MHz utilized in ITU Studies, significantly increases the area of possible harmful interference out to the horizon in line-of-sight environments as shown in Figure 12. Even with clutter loss which may be present in certain urban environments, harmful interference from a single base station is possible out to 3.6 km. Interference from multiple base stations would result in a cumulative effect on probability of interference and therefore the interference area and would be dramatically greater at reported IMT base station densities. Such large interference areas around even a single base station would significantly constrain deployment of base stations, SBCS UTs, or both. Again, this analysis still assumes the narrowly defined antenna characteristics, geometry, and user equipment distribution defined for ITU Studies and as discussed for interference into fixed wireless service, alternative use cases permitted by UMFUS could dramatically increase the level and impact of interference. And, once more, the effects of multiple nearby base stations would be cumulative.

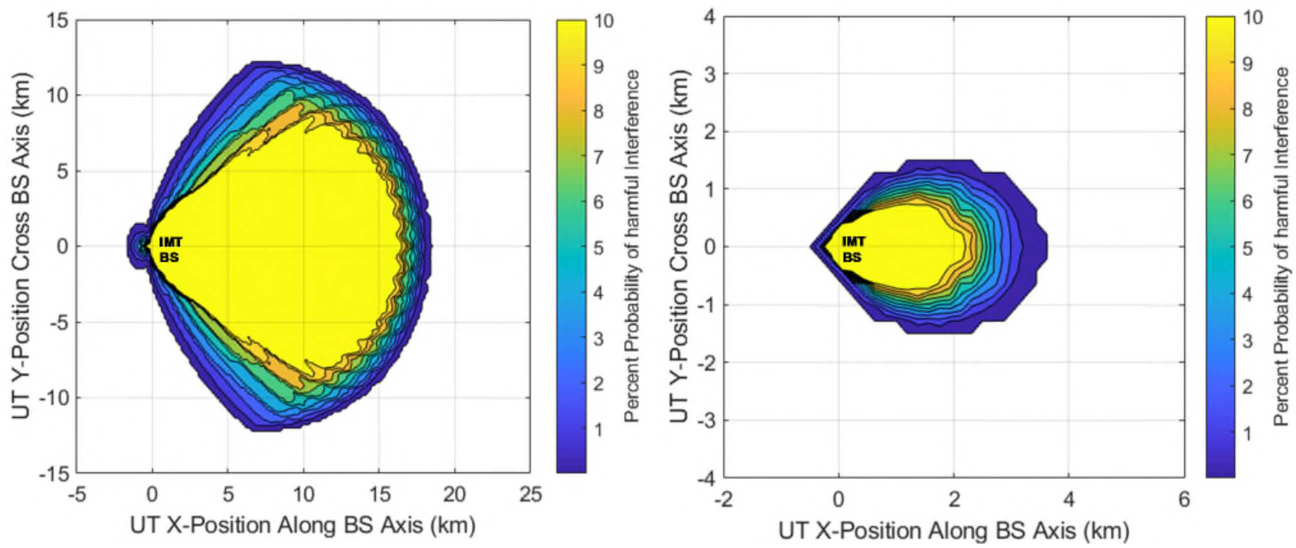

Figure 12: Percent probability of interference from base station into SBCS Consumer UT in worst case with UMFUS EIRP density with line-of-sight (left) and with clutter loss (right). Contours depict probability based on ITU probability distribution for user equipment locations in base station reference.

3. Prospects for mitigating interference from a theoretical UMFUS base station

The Commission asks for comment on "spectrum-sharing techniques that might reduce the required separation distances between UMFUS equipment and ground stations communicating with airborne platforms."[162] Sharing techniques theoretically exist that could reduce the required separation distances between UMFUS stations (and the deployments of other services) to permit compatibility, but the methods may not be practical. Some candidate techniques might include constraints on UMFUS base station beamforming to limit EIRP density projected in victim recover directions and spectrum segmentation on a localized basis. These limits could be imposed generally or become applicable in coordination between operations of UMFUS operators and incumbents. The effectiveness and practicality of these techniques, and

162 *Third FNPRM* at ¶ 87.

others that might be proposed, however, may only be subject to a full assessment once the use cases for UMFUS are posited sufficiently enough that they can be defined and analyzed.[163] Moreover, to assess the acceptability of these methods would require further detailed analysis of the impacts of other UMFUS operational freedoms as well and could benefit from field testing.

V. SBCS DEPLOYMENT IN THE U.S. IS DEPENDENT ON GIVING MULTIPLE OPERATORS AND TECHNOLOGIES ACCESS TO THE 26 GHz BAND AND THE OTHER PROPOSED SBCS BANDS OUTSIDE OF AN UMFUS REGULATORY FRAMEWORK

A. Assuming *Arguendo* that UMFUS Were to Be Authorized in the 26 GHz Band, SBCS Eligibility Limited to Individual UMFUS Licensees Is Highly Unlikely to Generate Investment in Development and Deployment of SBCS Systems

The Commission inquires in the *Third FNPRM* whether it should constrain the ability to deploy SBCS to UMFUS licensees in the 26 GHz Band.[164] As an initial matter, the question presupposes that the Commission should make the 26 GHz Band available for UMFUS and presumably license the band on an exclusive basis. As explained in Sections II through IV in these comments, the Commission should not take that step, which could jeopardize the realization of advanced stratospheric solutions in this country.

Elefante Group respectfully interprets the Commission's question as asking whether stratospheric solutions will come to reality if it were only to permit UMFUS licensees to deploy stratospheric systems, *assuming, for the sake of argument, it were to license the 26 GHz Band to*

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163 Indeed, without well-defined use cases or a clear understanding of permitted technical and operational limits, compatibility becomes entirely unpredictable. Even the high positive harmful interference margins predicted for potential IMT-2020 interference into ISS might be eroded by different assumptions (*e.g.*, an orders of magnitude increase in emitters for IoT).

164 *Third FNPRM* at ¶ 87.

UMFUS operators on an exclusive basis and only permit UMFUS licensees to operate such systems. For several reasons, as explained below, Elefante Group submits the answer is "no."[165]

First and foremost, prohibiting deployment of SBCS systems, except to licensed UMFUS operators, would not afford the spectrum or coverage area that would achieve the return on investment needed to develop and deploy such systems.[166] UMFUS operators will be licensed on a pre-established geographic basis – presumably no larger than a Partial Economic Area ("PEA") – with only several hundred megahertz of spectrum available to them.[167] These limits, in combination, will constrain the service area over which the investments could be recovered and more importantly, the achievable throughput on an airship.

Though several contemplated limited capacity stratospheric programs have considered or are considering smaller coverage areas and/or reduced throughput to facilitate coverage in only

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[165] Despite taking this position on the question of whether only UMFUS licensees should be entitled to deploy SBCS, Elefante Group certainly has no objection if UMFUS operators (consistent with the applicable Commission rules) wish to deploy SBCS on a shared basis in the 26 GHz Band or within exclusively licensed spectrum in the 24, 28, 37, 39, and 47 GHz bands, although, on the grounds stated in this section, Elefante Group believes that UMFUS licensees are highly unlikely to do so.

[166] The timeframe and resources needed to build and deploy SBCS platforms are counter to the traditional capital utilization models of mobile operators and could represent commercial challenges to an UMFUS operator's business model. The model for deployment of terrestrial wireless infrastructure has largely been based on the desire for auctioned, exclusive use spectrum, *see January 2018 T-Mobile Comments* at 6-11 (requesting the Commission license spectrum in the 26, 32, 37, 42, and 50 GHz bands for exclusive use), which can then be deployed over the course of a license term, or an extended fraction thereof at a minimum, to satisfy applicable performance requirements. As noted in Section IV and Attachments A and B of these comments, use of the 26 GHz Band by UMFUS is not likely to allow continued growth of incumbent services or entrance of new services in the band. *Third FNPRM* at ¶¶ 79, 82 (seeking comment "on the best ways to protect existing incumbent operations and systems" and highlighting the importance of "spectrum sharing and compatibility among diverse participants").

[167] Elefante Group notes that the Commission seeks comment on license sizes of 100 and 200 megahertz in the 26 GHz Band. *Third FNPRM* at ¶¶ 90-92.

rural or remote areas, smaller scale stratospheric deployments will, in Elefante Group's opinion, underachieve the potential benefits of SBCS in rural areas. Smaller scale systems will be incapable of realistically supporting the 5G and broadband capacity needs of urban areas when compared to the planned 1 Tbps SBCS system proposed by Elefante Group. As Elefante Group has explained in its *Petition* and earlier in these comments, the SBCS system it proposes will meet several Commission objectives in urban as well as rural areas, for example, helping to accelerate the rollout of next-generation services in both areas.[168] In rural areas, a SBCS will support the provision of the same level of next-generation services that urban areas expect to enjoy. Coverage-constrained and low throughput stratospheric services will not deliver these benefits. Accordingly, restricting SBCS opportunities only to individual UMFUS licensees, PEA (or smaller) operating areas, and limited bandwidths only allowing for aggregation of several hundred megahertz will not, in Elefante Group's opinion, support investment in advanced, high-capacity STRAPS and SBCS ground systems.

Elefante Group and Lockheed Martin have been studying these issues for several years and Elefante Group's determination is that capabilities of 1 Tbps over a 70 km radius (~ 15,000 sq km/6,000 mi^2), coupled with station-keeping and mission duration supporting urban in addition to rural operations, is needed to support the investment. Elefante Group submits that, were the Commission to extend its approach to geographic licensing to the stratosphere,[169] the Commission only would reinforce traditional ground-based technologies rather than allow innovative solutions such as SBCS to emerge, complement ground-based and satellite systems, and compete in the marketplace.

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168 *See, e.g., Petition* at 2-6; Comments of Elefante Group, Inc. on the Second Further Notice of Proposed Rulemaking, GN Docket No. 14-177, *et al.*, at 2-3 (Jan. 23, 2018).

169 *Third FNPRM* at ¶ 88.

Second, Elefante Group has analyzed the market in the United States and several other countries, and conducted discussions with multiple telecommunications operators here and abroad, and concluded that the optimum solution for SBCS is a wholesale product model supporting multiple providers by offering finished products for providers to integrate into their offerings or resell to individual customers. By supporting multiple services, Elefante Group's SBCS would allow customers specializing in specific market verticals to offer new services or grow existing ones with a high degree of flexibility.[170] Additional value added services can be layered on top of SBCS wholesale services, such as Smart City applications, enterprise WAN monitoring and management, and Smart Grid applications, to name a few. In this way, what Elefante Group plans to offer follows in the footsteps of successful wholesale wireline offerings, such as the "partnership" programs of Verizon and similar approaches of other major wireline carriers, as well as the wholesale businesses of major commercial mobile carriers, which have allowed mobile virtual network operators to thrive.

A dedicated SBCS operator operating on a wholesale basis is, in Elefante Group's view, needed to bring the benefits that SBCS offers to the urban and rural marketplace. The wholesale approach will also not only bring service in the first instance to locations within a STRAPS coverage area, it will also foster a competitive environment in underserved areas. Through maximizing utilization of commercial off-the-shelf technologies in development of STRAPS and leveraging them for its communications payloads, Elefante Group will be developing and integrating multiple technologies and building airships longer than two football fields and nearly as wide. Beyond the tens of millions of dollars that have been and continue to be invested in the design and development of the airships and communications platforms, building upon

[170] *Petition* at 22-29.

considerably larger investments Lockheed Martin has made under government contracts in recent years, even more significant technology investment and construction costs will be incurred by Elefante Group before it begins to deploy STRAPS commercially. These include building new manufacturing and operations facilities that may each encompass several square miles of land. The costs of building airships as well as manufacturing and support facilities are a significant capital investment that is likely beyond the interests of many, if not all, individual mobile operators, either as too innovative or as an unwelcome drain of capital on their existing and planned projects to densify their networks and deploy next-generation network facilities to take advantage of new low-, mid-, and high-band spectrum holdings. Elefante Group submits that only a dedicated SBCS operator that makes high-capacity systems available on a wholesale basis can justify the required development, integration, construction, and operational costs of SBCS.[171]

The solutions developed by Elefante Group (working with Lockheed Martin on the airship and communications technologies) contain the technical requirements to share the capacity of STRAPS between multiple wholesale customers. Ongoing investment in research has yielded multiple "Network in the Sky" technological communication advances, including the ability to support hundreds of individual beams, very high speed switching of traffic from beam to beam without transitioning through a gateway or other ground network facilities to provide

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[171] Development and ongoing operation of SBCS platforms, such as those proposed by Elefante Group, are significant challenges that require the focus of a single purpose entity. Stratospheric airships being developed by Elefante Group share affinities with paradigm-shifting projects being developed and tested by others such as Loon, Aquila, or Stratobus, such as unique mission planning, new applications for commercial off-the-shelf equipment, advanced materials, low-speed aerodynamics, and new payloads. The fruits of fielding a platform by a single purpose entity that provides 1 Tbps capacity over nearly 6,000 mi^2 in multiple product offerings can be shared with multiple service providers.

connectivity, support for enterprise functionality such as virtual private networking and quality of service, and class of service, all with low latency, and the ability to maintain the service consistently through STRAPS missions of six-to-twelve month duration (and "hot" STRAPS-STRAPS handovers at the end of missions) with station-keeping over the service area. By delivering traditional telecommunications solutions through multiple wholesale customers, the capabilities and operational costs of an SBCS can be shared across the services wholesale customers provide to end users.

Third, the ability to deploy advanced ground-based systems within a certain amount of spectrum does not translate to the ability to deploy economically feasible systems in the stratosphere within the same bandwidth. For any SBCS system, the amount of available spectrum is directly related to overall airship capacity. While license sizes of 100 or 200 megahertz[172] of mmW spectrum may serve localized ground-based deployments, given the very small cell architectures possible, they would not provide sufficient spectrum for meaningful stratospheric systems. Various technological advances are available for use in ground-based 5G systems, such as massive MIMO, that are not equally available for use from a stratospheric platform. Multiple larger channel sizes for stratospheric use, to allow for a spectrum beam reuse pattern of N equal to at least three or four across hundreds of beams, are needed to enable SBCS operators to provide services with sufficient throughput to support next-generation solutions throughout a large coverage area. Fortunately, as Elefante Group has demonstrated, sufficient suitable spectrum, albeit encumbered, is available in the Ka-Band as described in its *Petition*, including the 26 GHz Band, and can be shared.[173] If given access to share this spectrum, SBCS

[172] *Third FNPRM* at ¶ 91.

[173] *Petition* at 87-92.

systems can use the spectrum in a compatible manner with incumbent services, including other SBCS operators,[174] and, in the case of Elefante Group, provide 1 Tbps of full duplex services to facilitate the deployment of ground based 4G and 5G services.

Fourth, limiting 26 GHz Band usage to PEAs[175] (or some smaller geographic license area) would be a geographical mismatch and would not be supportive of the technical capabilities of SBCS, and the Elefante Group contemplated SBCS, in particular. The technology available to distribute 1 Tbps of capacity over a 6,000 mi^2 area is unique and different than proposals to which such geographic licensing may be suited, *i.e.*, to use technologies that are outgrowths of traditional cellular and point-to-point technologies that will measure coverage distances in tens of meters, perhaps up to one hundred meters or so, at 26 GHz. Such cellular and point-to-point technologies also are delivered within the licensed area – which differ radically in size and shape from one PEA to another[176] – on a more granular site-by-site basis, instead of being able to provide service over a 6,000 mi^2 coverage area made possible all at once with the launch of a single STRAPS.

B. Assuming *Arguendo* that UMFUS Were to Be Given Access to the 26 GHz Band, the Value of the SBCS Solution Will Be Minimized If Limited to Individual UMFUS Licensees

Limiting use of an SBCS to individual UMFUS licensees[177] is impractical and ignores the complexities of operation of stratospheric platforms. In addition to the issues of geographic

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174 *See generally id.* at Appendices B-U; *Elefante Group Petition Reply Comments* at Exhibits 2-9.

175 *Third FNPRM* at ¶ 89 (seeking comment on geographic license size for any putative UMFUS licenses).

176 *See Wireless Telecommunications Bureau Provides Details About Partial Economic Areas*, GN Docket No. 12-268, Public Notice, 29 FCC Rcd 6491, Appendix C (2014).

177 *Third FNPRM* at ¶ 87.

licensing, as noted in the previous subsection, limiting stratospheric platforms to operation by UMFUS licensees on an individual basis within the scope of their UMFUS licenses ignores the necessary investment and expertise necessary to design and deploy SBCS, including the complexities of integrating multiple communications technologies, building an airship with advanced material characteristics, helium retention issues, obtaining airworthiness certifications, mission planning and execution, constructing new manufacturing and operations facilities large enough to accommodate a fleet of airships, and stratospheric operation. UMFUS operators are likely to be traditional telecommunications operators, either mobile or fixed, that are well versed in terrestrial technologies.[178] Such operators are not well versed in deploying stratospheric platforms, including the specialized technologies needed to place 1 Tbps capacity in the stratosphere with station-keeping for six-to-twelve-month duration missions. Fleet operations of platforms at the size planned by the Elefante Group STRAPS, or sophisticated fixed wing aircraft or alternate solutions proposed by others, require specialized mission planning and execution functions that are best met by an independent organization not associated with a single UMFUS operator, and are best shared across multiple SBCS customers in a wholesale market model, as discussed above. Operation of a stratospheric platform by UMFUS license holders understandably would be well outside the expertise and "comfort zone" of those licensees given their current focus.

Another example demonstrates how UMFUS-licensee-specific stratospheric systems, setting aside the difficulties with such systems already addressed, would likely fail to support a

[178] The imminent 24 and 28 GHz auctions commencing in November 2018 may well bear this out. *See Auctions of Upper Microwave Flexible Use Licensees for Next-Generation Wireless Services*, AU Docket No. 18-85, FCC 18-109 (Aug. 3, 2018); *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, GN Docket No. 14-177, Fourth Further Notice of Proposed Rulemaking, FCC 18-110 (Aug. 3, 2018).

key feature of SBCS systems as envisioned by Elefante Group's *Petition*. The full capabilities of SBCS operations to meet communications needs during and after man-made and natural disasters will not be realized if limited to a single UMFUS operator in a licensed area.[179] Quick restoration of network backhaul capabilities and broadband access connectivity, a key feature of stratospheric operations above and in the wake of significant weather events, will not be fully realized if limited to a single UMFUS operator. Though services were provided over Puerto Rico after Hurricane Maria utilizing a free-floating stratospheric platform, the coverage was limited in geographic scope and continuity of coverage. Both coverage and service continuity were severely affected by Loon's need to serially launch multiple balloons and rely on an uncertain ability to predict wind conditions to maintain coverage over the desired target area. Though a significant contribution to the citizens of Puerto Rico, Spectrum Financial Partners, LLC estimated that for only one day in their analysis was the entire island of Puerto Rico fully within range of the Loon balloons.[180] In comparison, STRAPS with station-keeping capabilities (power/propulsion/navigation) could have targeted wide area coverage over the main island and maintained station for a mission duration of six or more months, with a hot cut-over to successor STRAPS to preserve continuity of service.

VI. THE COMMISSION SHOULD EXPAND THIS PROCEEDING TO ALLOW A COMPREHENSIVE CONSIDERATION OF FUTURE USES OF THE 26 GHz BAND, INCLUDING SBCS RULES

At present, the Commission has before it two major initiatives begun almost simultaneously regarding the future use of the 26 GHz Band: (1) Elefante Group's *Petition* filed

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179 *See generally* Comments of the Elefante Group, Inc., PS Docket No. 17-344 (Jan. 22, 2018).

180 *See* Spectrum Financial Partners, LLC, Comments for PSHSB Docket No. 17-344, Public Safety and Homeland Security Bureau Seek Comments on Response Efforts Undertaken During 2017 Hurricane Season (Jan. 21, 2018).

May 31, 2018, and placed on Public Notice on June 11, 2018,[181] and (2) the consideration of the 26 GHz Band in the *Third FNPRM*, which was adopted June 8, 2018, one business day prior to the Public Notice of the *Petition*.[182] Both of these initiatives focused on the 26 GHz Band were first hinted at before the Commission publicly in comments filed at the beginning of the year by Elefante Group and members of the mobile industry in the *Spectrum Frontiers* proceeding.[183]

Given that the *Petition* and the *Spectrum Frontiers* proceeding simultaneously raised the question of future uses of the 26 GHz Band, Elefante Group submits that the Commission should consider possible new uses of the 26 GHz Band in a comprehensive fashion. The Commission should not prejudge access to the spectrum by either SBCS or flexible mobile use. In this regard, Elefante Group agrees with the comments of CTIA and T-Mobile on the *Petition* that the Commission proceed to consider Elefante Group's proposal in a comprehensive fashion with possible introduction of some form of flexible fixed and/or mobile use.[184] Further, to ensure that it can adopt SBCS rules in an administratively efficient fashion, the Commission should

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181 *See generally Petition*; *Petition Public Notice*.

182 *Third FNPRM* at ¶¶ 75-91.

183 As the result of many months of analysis in 2017, Elefante Group homed in on the 26 GHz Band as the most suitable candidate for downlink spectrum to allow its SBCS design to achieve the 1 Tbps performance requirement. *See supra* at Section II.

184 *See* Opposition of CTIA, RM-11809, at 1 (July 11, 2018) ("[I]f the Commission determines to evaluate the issues raised by the Elefante Petition relating to the 25.25-27.5 GHz ('26 GHz') band, it should do so within the context of the pending *Spectrum Frontiers* docket."); Opposition of T-Mobile USA, Inc., RM 11809, at 8 (July 11, 2018) (recommending that Elefante Group's *Petition* should be "considered in light of the Commission's ongoing *Spectrum Frontiers* proceeding"). While these two parties were concerned with the potential for the Commission to consider rules for SBCS separately from, and in advance of, addressing to what extent and under what conditions other new services, such as UMFUS, might be granted access to the 26 GHz Band, Elefante Group believes that a comprehensive examination of new service options generally is the correct approach.

consolidate consideration of proposed SBCS bands generally (in the 22-23 and 70/80 GHz Bands, in addition to the 26 GHz Band) in the *Spectrum Frontiers* proceeding.

In the *Third FNPRM*, the Commission raises numerous questions regarding potential SBCS operations in the 26 GHz Band.[185] For example, recognizing the pendency of the *Petition,* the *Third FNPRM* inquires as to the compatibility between SBCS and flexible mobile – both of which the Commission brands as "New Services."[186] In fact that part of the *Third FNPRM* is entitled "Spectrum Sharing and Compatibility with *Other* New Services."[187] The Commission seeks comment – which Elefante Group provides in Section IV above and in several of the Attachments to these comments – on the question of whether "spectrum sharing between airborne platform services (*i.e.*, both HAPS and systems such as Elefante's that would operate at lower altitudes) and unaffiliated UMFUS operators would be infeasible."[188] More specifically, the *Third FNPRM* requests information on "spectrum-sharing techniques that might reduce the required separation distances between UMFUS equipment and ground stations communicating with airborne platforms."[189] The Commission also raises the question whether, in effect, to accommodate stratospheric platform services, "UMFUS should therefore not be authorized in the 26 GHz band."[190] On the flip side, the Commission inquires whether it "should prohibit airborne

185 *Third FNPRM* at ¶¶ 79-91.

186 *Id.* at ¶¶ 85-87.

187 *Id.* (emphasis added).

188 *Id.* at ¶ 87.

189 *Id.*

190 *Id.*

platform systems in the band, or authorize airborne platform services only if they are affiliated with UMFUS licensees."[191]

Although the Commission clearly raises questions as to whether UMFUS should be excluded from the 26 GHz Band if such service cannot share with SBCS, and whether, in the alternative, SBCS should be excluded from the band in favor of UMFUS, the *Third FNPRM* does not affirmatively raise the question of whether SBCS should be permitted in the band (and, if so, what the service rules should be). This last question, however, is ripe and the record has been extensively developed regarding the ways in which sharing by SBCS with incumbent services can be achieved – both in the 26 GHz Band, but also the 22-23 GHz and 70/80 GHz Bands.[192] Accordingly, the Commission should either clarify the *Third FNPRM* to allow a comprehensive examination and timely adoption of SBCS rules (in their entirety) or, in the alternative, swiftly issue a Further Notice of Proposed Rulemaking in the *Spectrum Frontiers* proceeding to effectuate the consolidation. Such action will permit the Commission the flexibility to address the introduction of SBCS and UMFUS, or a decision to permit one but not the other, without any prejudgment. A new Further Notice of Proposed Rulemaking would be the best method of ensuring that all aspects of the *Petition*'s SBCS proposal are before the

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191 *Id.* Elefante Group addresses in Section V, *supra*, the question of whether airborne platforms should be permitted in the 26 GHz Band only if affiliated with UMFUS licensees, demonstrating that limiting airborne platforms to such licensees will most likely render deployment of SBCS-like services infeasible.

192 Elefante Group notes that the 70/80 GHz Bands have already been the subject of an earlier NPRM in this proceeding. *See First Spectrum Frontiers FNPRM* at ¶¶ 424-441. As Elefante Group explained in its Reply Comments on its *Petition*, while the Commission determined in the *Second Spectrum Frontiers Order* to consider proposals by emergent services, such as SBCS, to use the 70/80 GHz Bands in the *Wireless Backhaul* proceeding, *see Second Spectrum Frontiers Order* at ¶ 201, the Commission has the flexibility to change course. *Elefante Group Petition Reply Comments* at 54-64. This is particularly the case because no further steps have been taken in the *Wireless Backhaul* proceeding since November 2017.

Commission and ripe for rulemaking decision (*i.e.*, use of the 22-23 GHz Band and the 70/80 GHz Bands for SBCS, in addition to the 26 GHz Band), which will allow the Commission to take comprehensive action to make SBCS a reality. Issuing another Further Notice of Proposed Rulemaking on the 26 GHz Band would not be dissimilar to other aspects of this proceeding.[193] Beginning a new proceeding to address SBCS *independently*, when there are spectrum bands so intertwined with the *Spectrum Frontiers* proceeding, risks failing to consider the various uses of the bands holistically, and are proceeding pre-judging the other.

Finally, consolidating consideration of SBCS into the *Spectrum Frontiers* proceeding via a Further Notice of Proposed Rulemaking would not cause any undue delay in consideration of UMFUS. The Commission just launched this part of the *Spectrum Frontiers* proceeding and, unlike SBCS, virtually no record – prior to the instant round of comments – has been developed at the Commission on the use of the band by UMFUS. Compatibility studies are just now being filed publicly before the Commission, such as the Attachments hereto, in this round of comments, and it will take some time for interested parties to analyze and respond. More broadly, the Commission is only later this year instituting the first two auctions of mmW bands, at 24 and 28 GHz, and the expectation is that it will be another year or more before auctions can begin at 37, 39, and 47 GHz.[194] Consequently, issuing a Further Notice of Proposed Rulemaking to consolidate consideration of SBCS and UMFUS to ensure full consideration of the new uses

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[193] By way of comparison, the Commission has issued multiple notices within the *Spectrum Frontiers* proceeding to address the regulatory framework in the shared 37.0-37.6 GHz range, the so-called Lower 37 GHz Band. *See, e.g.*, *Third FNPRM* at ¶¶ 26-29; *First Spectrum Frontiers Order* at ¶ 105.

[194] *See Auctions of Upper Microwave Flexible Use Licensees for Next-Generation Wireless Services*, AU Docket No. 18-85, FCC 18-109 (Aug. 3, 2018); *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, GN Docket No. 14-177, Fourth Further Notice of Proposed Rulemaking, FCC 18-110 (Aug. 3, 2018).

to which the 26 GHz Band can be put – in addition to the incumbent services – need not cause any delay, should the Commission conclude to permit flexible mobile or fixed users access to all or part of the band. By contrast, putting off consideration of SBCS rules would risk depriving U.S. markets timely access to stratospheric solutions, which, as Elefante Group has explained at length in its *Petition*, can play an essential complementary role to ground-based terrestrial and satellite applications in bringing rapid delivery of next-generation solutions to all Americans.[195]

The Commission also should include consideration of the 22-23 GHz Band and the 70/80 GHz Bands for SBCS in the *Spectrum Frontiers* proceeding. Delays in starting a separate SBCS proceeding could risk the Commission taking actions in the *Spectrum Frontiers* proceeding regarding the 26 GHz Band that would likely have a severe impact on the Commission's ability to authorize SBCS to help win the race to 5G, close the digital divide, and meet public safety communications needs during weather events.[196] As discussed in Section II above and in Section VII of the *Petition*, the 22-23 GHz Band, the 26 GHz Band, and the 70/80 GHz Bands were deliberately and holistically chosen by Elefante Group for proposed SBCS in the *Petition* and the inability to effectively share use of the 26 GHz Band would greatly impact SBCS use of the 22-23 GHz Band for STRAPS-UT links and the E-band spectrum for feeder links because the entire SBCS proposal could be undermined.[197]

Finally, by consolidating in the *Spectrum Frontiers* proceeding, as requested herein, consideration of a regulatory framework to facilitate the timely introduction SBCS in this country, the Commission would serve the purposes, and requirements, of Section 7 of the Act.

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195 *Petition* at 41-48.

196 *See id.* at 3.

197 *See id.* at 55-81.

In its *Petition*, Elefante Group requested treatment of its proposal for SBCS as a "new technology and service" under Section 7, obligating the Commission to act regarding SBCS within twelve months.[198] Specifically, Elefante Group requested that the Commission issue a notice of proposed rulemaking within one year, and then adopt rules within twelve months of releasing such notice. By consolidating consideration of SBCS rules comprehensively in the *Spectrum Frontiers* proceeding, the Commission will satisfy the first half of this requested relief as well as the dictates under the statute.

VII. CONCLUSION

For the foregoing reasons, Elefante Group respectfully requests that the Commission expeditiously consolidate consideration of SBCS rules in this proceeding, issuing a Further Notice of Proposed Rulemaking if it deems it procedurally necessary. The Commission should continue on the path to facilitating the introduction of SBCS as proposed in Elefante Group's *Petition* in the SBCS Bands, including the 26 GHz Band, and the many public benefits that this new innovative service will bring. At the same time, the Commission should move with caution in considering whether to introduce flexible mobile use, *i.e.*, UMFUS, in the 26 GHz Band due to the serious concerns as to whether flexible mobile services can operate compatibly with incumbent services as well as SBCS, as demonstrated herein and in the Attachments hereto. Indeed, unless the Commission concludes that UMFUS can operate in the 26 GHz Band on a compatible basis with incumbents and SBCS, the Commission should not provide flexible mobile services access to the Band and jeopardize the realization of advanced stratospheric-based communications in this country. Elefante Group looks forward to continuing to examine

198 *See id.* at 106-107.

these issues of compatibility with the Commission and invites dialogue with the commercial mobile industry in response to their comments on the *Third FNPRM*.

Respectfully submitted,

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Attachment A
Compatibility Analysis:
IMT BS & UMFUS Interference into Federal Fixed Services in the
24.25-27.5 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- This study assesses the compatibility with Federal Fixed Services (FS) authorized to operate as Primary in the 24.25-27.5 GHz band of possible commercial mobile Base Stations (BS) in a user access link-type configuration as envisioned in IMT-2020 studies and then extends the analysis using UMFUS permitted in-band transmissions.

- ITU IMT BS characteristics and User Equipment (UE) distribution statistics are initially utilized to determine the required separation distance between a single IMT BS and FS receiver to meet the FS I/N Protection Criteria with and without clutter loss. The analysis is repeated using UMFUS permitted EIRP density for the base station.

- Time-variant factors, typically included in ITU statistical analyses, are not included to better represent scenarios where the local interference environment is dominated by one or more base stations.

- Study results show that large separation distances of 6-30 km are required to avoid line-of-sight interference from a single IMT BS. Clutter loss in dense urban environments reduces this distance though it remains large at the FS receiver boresight and is still much larger than the 120 m coverage distance of a single IMT hotspot. Interference from multiple IMT BS would be cumulative and considering published densities of IMT BS, could severely impact existing FS installations and constrain one or both systems.

- Utilizing the EIRP density allowable under UMFUS, the harmful interference area (i.e. where I/N exceeds the Protection Criterion) due to a single base station is beyond the horizon when there is clear line-of-sight and doesn't improve much even with inclusion of clutter loss which, in any event, may only be present in some urban deployments.

- To improve the analysis even further, given the presumed ability of UMFUS operators to operate base stations in configurations and use cases other than the one evaluated in the ITU Studies and in this Attachment, other use cases involving less base station downtilt, a denser deployment of base stations, alternative UE distributions, the introduction of cross-links between base stations, and other variables could be included in future analyses.

PURPOSE OF THE STUDY

Currently published ITU studies of IMT-2020 compatibility with Fixed Service apply deterministic or Monte Carlo statistical method under varying scenarios. The deterministic studies are helpful to illustrate the worst-case bounding conditions; however, the resultant large separation distances required generally do not support co-existence with Fixed Service receivers in the same frequencies.

Studies utilizing Monte Carlo statistical methods attempted to quantify the likelihood of interference as a function of separation distance but included all possible statistical parameters which would be warranted for aggregate risk assessment. Such studies conclude that detailed coordination would be required on a case-by-case basis to permit co-existence; however, such studies, focused on aggregate risks, understate the problems of coexistence. The studies include statistical parameters which consider effects over long durations or large coverage areas, but, by doing so, they mask whether coordination is practical in real scenarios where the local environment and use cases would dominate.

The purpose of this study is to determine likelihood of harmful interference at varying separation distances due to interference from IMT-2020 base stations configured to provide user access links as evaluated in the ITU studies but with modified operational and environmental assumptions and, subsequently using UMFUS-permitted EIRP density, designed to represent the potential local interference environment seen by an FS receiver.

PARAMETERS UTILIZED FOR STUDY

Table 1and Table 2 present IMT-2020 compatibility analysis parameters utilized for this study. FS receive characteristics utilized for this study are shown in Table 3.

UMFUS maximum base station EIRP density of 25 dBW/MHz is based on 75 dBm/100 MHz EIRP density specified in the Federal Communications Commission’s (FCC’s) rules for UMFUS (see 47 C.F.R. §30.202). This study examines the effect of the higher EIRP density permitted by UMFUS rules while assuming IMT-2020 characteristics for the other parameters.

Table 1: Technical and operational characteristics of IMT-2020 systems

	Parameters from expert WPs and TG 5/1 Ad-Hoc Group	Elefante Group Study
Deployment scenario	Outdoor urban hotspot, Outdoor suburban hotspot, Outdoor suburban open space hotspot (optional), Indoor	Outdoor urban hotspot, Outdoor suburban open space hotspot
IMT stations	BS and UE	BS
Method to deploy multiple IMT stations for the aggregated interference analysis over a relatively large area (as applicable to scenarios for the studies)	**Ra and Rb method:** Ra: Urban (Outdoor): 7%, Suburban (Outdoor): 3%, Urban (Indoor) 2%, Suburban (Indoor) 1% Rb: 5%	Not applicable
Number of IMT-2020 stations	–	1 BS
Network loading factor for BS and UE (%)	20	Not applicable
TDD activity factor (%)	BS: 80, UE: 20	Not applicable
UE power control factor (dB)	Section 2.3 in Rec. ITU-R M.2101 and Items 2.2, 2.3 and 2.4 in Table 11 in Attachment 2 to Doc. 5-1/36	Not applicable
UE body loss (dB)	4	Not applicable
IMT Antenna pattern	Rec ITU-R M.2101	Rec ITU-R M.2101
Normalization of antenna gain	Additional guidance (or further clarification) is found in Annex 1 to the Chairman's Report	Not applicable
BS antenna pointing	Mechanical pointing in elevation (downtilt angle of 10°) and azimuth	10° down-tilt for the BS. BS beam points towards UEs
UE antenna pointing	Randomly in elevation in the range -90° to 90° and in azimuth in the range -60° to +60° in the direction of the BS.	Not applicable

Table 2: IMT-2020 Base Station Transmit Characteristics

Parameter	Value	Notes
Antenna Height	6m above ground level	Radiation Center
Element Gain	5 dBi	
3 dB Beamwidth of Single Element	65º	For both H/V
Front-to-Back Ratio	30 dB	For both H/V
Antenna array configuration	8x8 elements	(Row x Column)
Radiating Element Spacing	0.5 of wavelength	For both H/V
Maximum Power into Antenna	28 dBm	
Array Ohmic loss	3 dB	
Peak Antenna Gain	23 dBi	
Maximum EIRP Density	-4.9 dBW/MHz	Calculated from above

Table 3: Technical and operational characteristics of FS

	Parameters from expert WPs and TG 5/1 Ad-Hoc Group	Elefante Group Study
Channel spacing and receiver noise bandwidth (MHz)	See Document 5-1/31 3.5, 7, 14, 28, 56, 112	28
Receive antenna gain (dBi)	See Document 5-1/31 Rec. ITU-R F.758-6 31.5-48 dBi	36.6
Noise figure (dB)	See Document 5-1/31 Rec. ITU-R F.758-6 6.5	6.5
Antenna diameter (m)	See Document 5-1/31	0.3
Peak transmit antenna gain (dBi)	See Document 5-1/31	36.6
Antenna gain pattern	See Document 5-1/31 Rec. ITU-R F.699-7	Rec. ITU-R F.699-7
Elevation angle (degrees)	See Document 5-1/31 Rec. ITU-R F.758-6 (-2.5 to +2.5)	0
Station height (m)		20
Protection criterion (Long Term, 20% of Time) I/N, (dB) (See Document ITU 5-1/89)	See Document 5-1/31 Rec. ITU-R F.758-6 -10	-10 dB; however, applied to short term 1% criterion since unclear if 20% long term criterion is applicable for IMT BS interference in a local environment
Apportionment value (dB)	Included in the I/N above	Not applicable
Baseline	See Document 5-1/38	Rec. ITU-R P.452-16
Atmospheric gases loss	See Document 5-1/38	Rec. ITU-R P.452-16
Clutter loss	Rec. ITU-R P.2108	Rec. ITU-R P.2108
Building entry loss	Rec. ITU-R P.2109	Not applicable
Cross-polarization loss (dB)	Additional guidance (or further clarification) is found in Annex 1 to the Chairman's Report	Not applicable

STUDY SCENARIO

Figure 1 and Figure 2 illustrate the interference geometry utilized for this study.

- An IMT-2020 BS using electronic steering directs a transmit beam at maximum power towards an active IMT UE.
- An FS receiver at 20 m height receives the desired signal from an FS transmitter at 20 m height and also receives an interference signal from the IMT BS assumed to be operating in the same frequency band.
- For a fixed location of the FS receiver, if a candidate IMT BS location and mechanical pointing direction of the IMT BS and the active IMT UE location are specified, the associated range, IMT BS transmit antenna gain towards the FS receiver, and FS receive antenna gain towards the IMT BS can be utilized to determine the level of interference and compared to the FS I/N Protection Criterion.
- The IMT UE location relative to the IMT BS is defined by probability density functions (pdf's) shown in ITU WP 5D/258(Rev 2). Therefore, the resultant I/N for a specific IMT BS location is also a pdf which can be expressed as likelihood of interference to exceed the I/N Protection Criterion.
- Results from above are applicable for situations for which there is line-of-sight visibility (no clutter) from the IMT BS to the FS receivers.
- Impact of clutter loss on results is also examined, using parameters specified by ITU-R P.2108, to determine improvements which may be realizable in specific urban environments.
- Time-variants factors which have been used in other ITU IMT studies are specifically not included in this study because they mask real world effects near individual base station locations. These factors include a Network Loading Factor, TDD Activity Factor and base station power division over multiple UEs. Such factors may be appropriate as part of aggregate statistical arguments applied over wide areas and long duration where impacts to specific FS links are ignored. However, these factors may not help with mitigating against harmful interference into a specific FS receiver which is determined by the local IMT deployment environment, geometry, and use-cases.

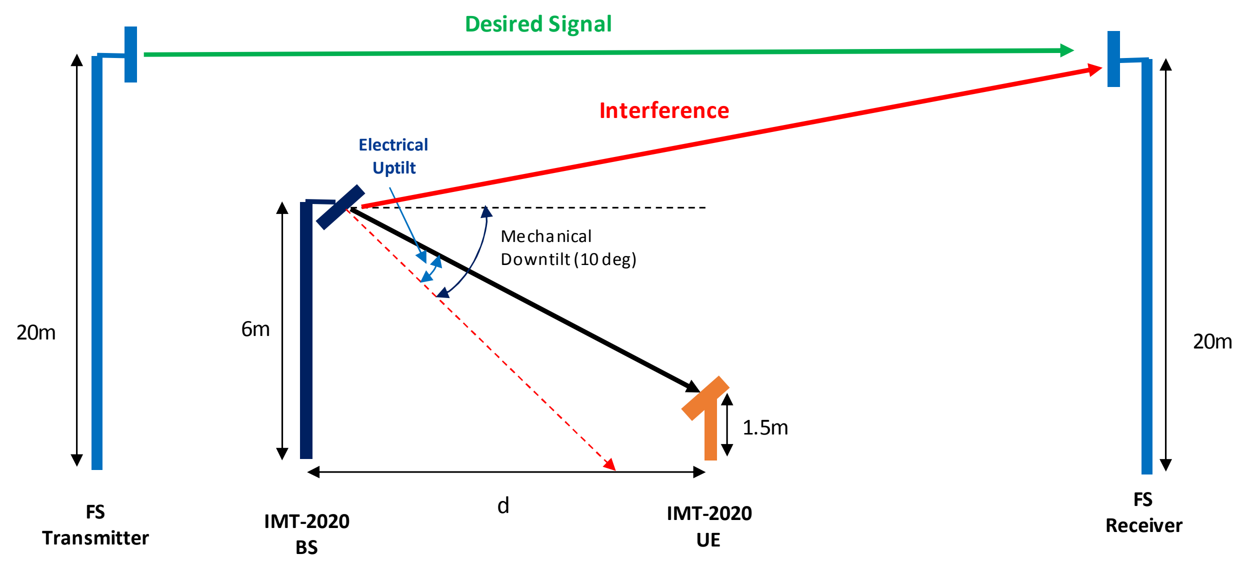

Figure 1: Interference Geometry – Elevation View

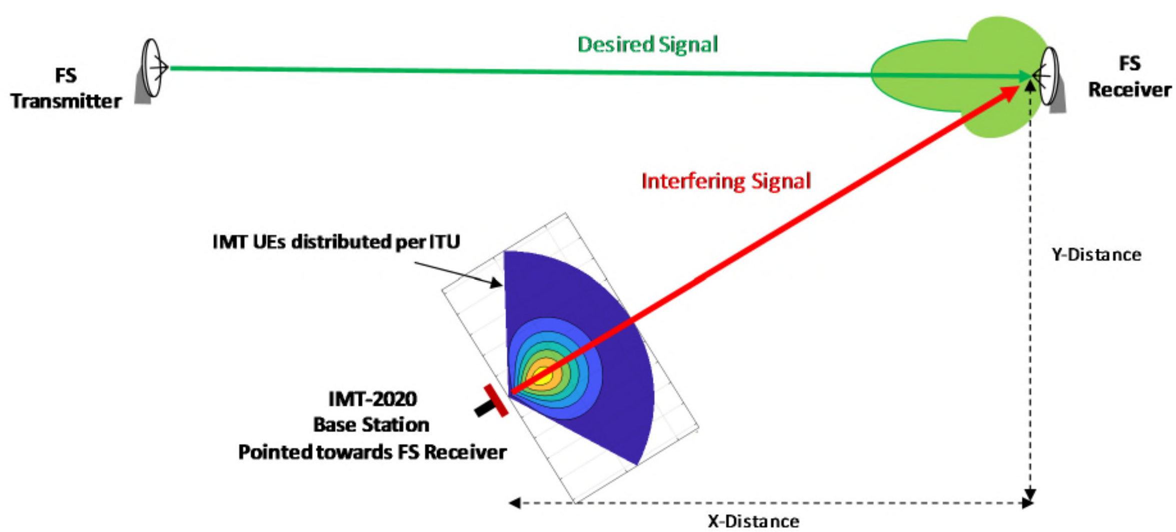

Figure 2: Interference Geometry - Plan View

STUDY METHODOLOGY

The study starts by assuming a single IMT BS is transmitting towards a single UE whose location is defined by probability density functions (pdf) as shown in Figure 3, the same as modeled in ITU studies. Specifically, the range to the UE is modeled as a Raleigh probability distribution with a characteristic value of 32 meters and the pointing direction of the IMT BS towards the UE is defined a normal distribution function with a standard deviation of 30 deg which is clipped at 60 degrees. The combined UE pdf is also illustrated in the figure and shows that the highest concentration of UEs is modeled as being concentrated at the IMT BS boresight and within 30-50 meters of the base station and the furthest UE is 120 m away.

It should be noted that although the ITU UE distributions were utilized in this analysis, other distributions are possible and may better represent real deployment situations for flexible mobile service. Therefore, the local interference environment near a victim receiver could be significantly different with a potential for higher level of interference.

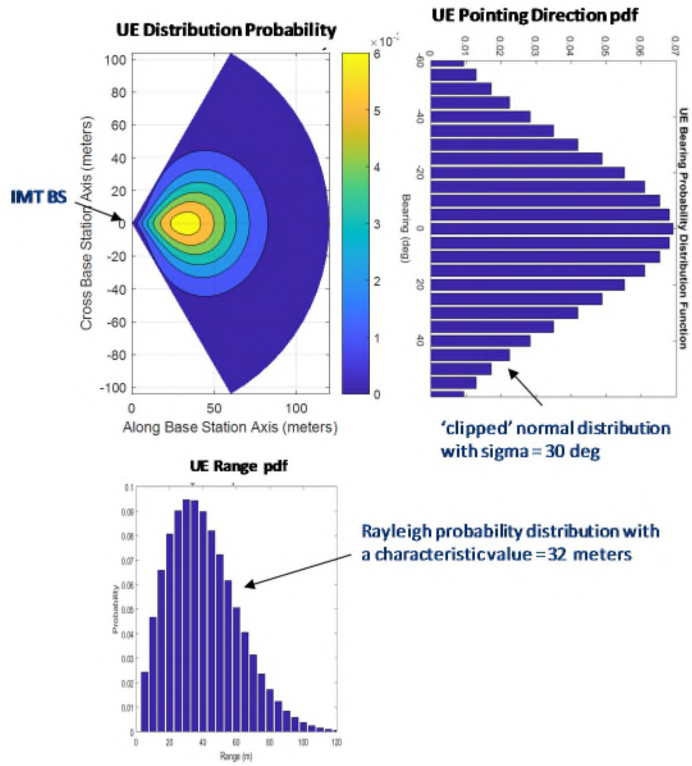

Figure 3: IMT UE distance and pointing direction probability density functions

As in ITU studies, the IMT BS antenna has its mechanical downtilt set at 10 deg while the boresight of the 8x8 array is electrically steered towards the active UE; sample antenna patterns are illustrated in Figure 4.

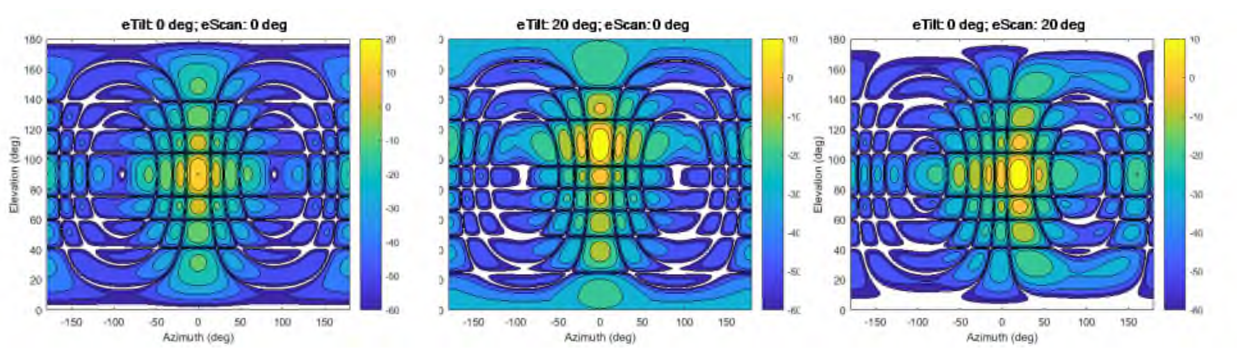

Figure 4: Sample IMT BS antenna patterns illustrating electrical steering towards the UE

To evaluate the BS EIRP towards a specific FS receiver location from various possible electrical pointing directions, a grid of UEs is first created over the IMT BS coverage area of +/- 60 degrees and range of 0-120 meters and then the corresponding IMT BS transmit antenna pattern at each grid point is determined as illustrated in Figure 5.

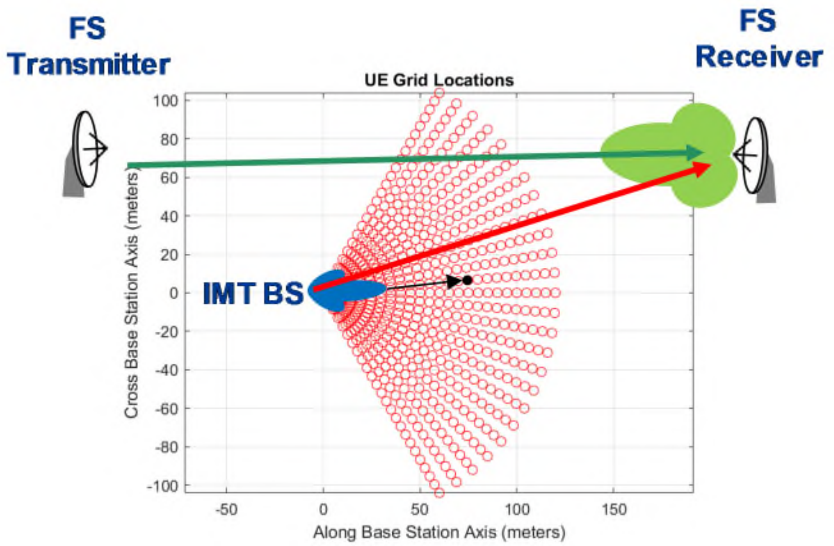

Figure 5: IMT BS EIRP towards FS receiver is a function of electrical pointing direction towards an active UE

Since there is a pdf associated with each UE location, by extension, there is a corresponding pdf associated with each IMT BS antenna pattern.

The I/N margin relative to the FS I/N Protection Criterion of -10 dB for specific locations of the FS receiver is calculated as follows:

$$Io(dBW/MHz) = EIRPDensity(\delta) - FSL - AtmLoss - Gr(\beta)$$

$$I/_N\ Margin\ (dB) = I/_N\ Threshold - (I_o - N_o)$$

where:

δ = Angle off IMT BS (Interferer) electrical boresight towards the FS receiver

$Gr\ (\beta)$ = FS Receiver (Victim) antenna gain off boresight towards IMT BS

FSL = Free Space Loss between the IMT BS and FS receiver

AtmLoss = Atmospheric loss as specified in ITU-R P.452-16 for p = 0.2

$I/_N\ Threshold$ is the FS I/N Protection Criterion of -10 dB

Since δ, the angle off IMT BS (Interferer) electrical boresight, towards the FS receiver is not a fixed value but dependent on the probability associated with UE location, the probability of the I/N margin being negative is calculated from the UE probability density and the individual I/N margins at each UE location as follows:

$$Pr(INM < 0) = \sum_{UE} \Pr(UE) * H(-INM_{UE})$$

where:

$Pr(INM < 0)$ is the probability that I/N Margin (INM) is negative

$\Pr(UE)$ is the probability of a user being at a specific UE grid location

INM_{UE} is the I/N margin associated with a specific UE grid location

H( ) is the Heaviside step function or the unit step function whose value is zero for a negative argument and one for a positive argument

The absolute I/N margin and the probability of negative I/N margin is calculated for varying relative locations of FS receivers and IMT BS in the reference frame of the FS receiver.

The analysis is repeated with inclusion of clutter loss using the ITU-R P.2108 model with 1% location probability, to represent the outdoor urban hotspot environment.

The analysis is also repeated with the 30 dB higher UMFUS EIRP density in contrast with the relatively benign EIRP density used in the ITU studies. Other UMFUS use cases such as with varying base station downtilt, beam width, antenna heights, antenna pattern and UE distribution have not yet been studied, but would be recommended for future studies since they would be expected to potentially present greater incidence of harmful interference and at greater distances alone and in combination.

It should be noted that the analysis is done assuming the IMT BS is pointed towards the FS receiver to understand possible constraints which may result in real deployment scenarios. This contrasts with ITU Monte Carlo based statistical analyses which attempt to characterize the likelihood of such alignment and therefore do not adequately address realistic scenarios when such alignment does occur.

STUDY RESULTS

Figure 6 illustrates the I/N margin for varying locations of the IMT BS with the IMT BS mechanical boresight azimuth angle pointed towards and having line-of-sight to the FS receiver when using the IMT customer access link scenario. The minimum separation distance even behind the FS receiver is more than 7 km while the separation distance at the FS boresight is greater than 30 km, well beyond the 14-16 km horizon with the assumed geometry.

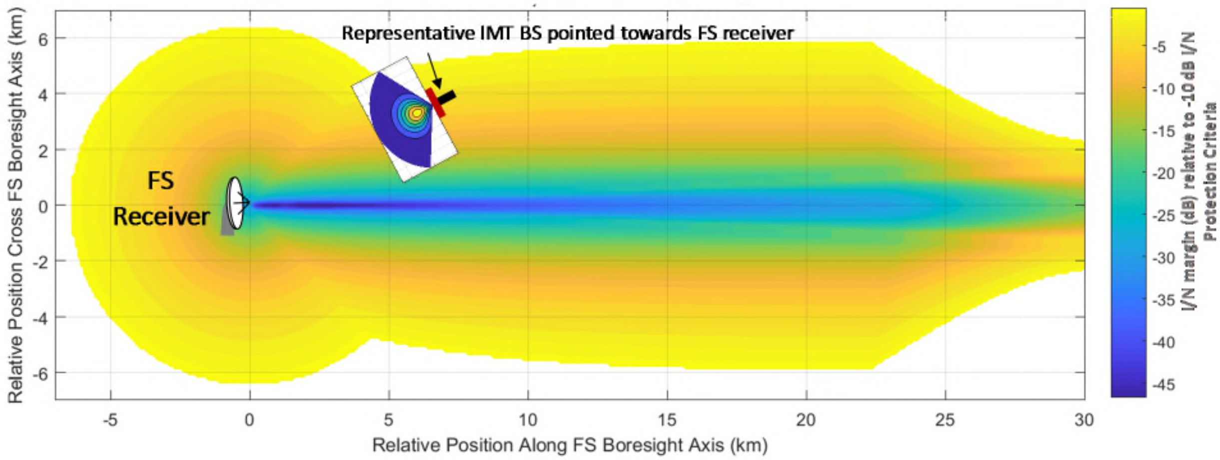

Figure 6: I/N Margin (dB) when IMT BS has line-of-sight (without clutter loss) and pointed in azimuth towards FS receiver

The corresponding percent probability of I/N margin exceeding the -10 dB I/N Protection Criterion is illustrated in Figure 7 when there is no clutter loss and shows that a majority of the area which has negative margin also has high probability of harmful interference well exceeding typical quality of service requirements of <<1%.

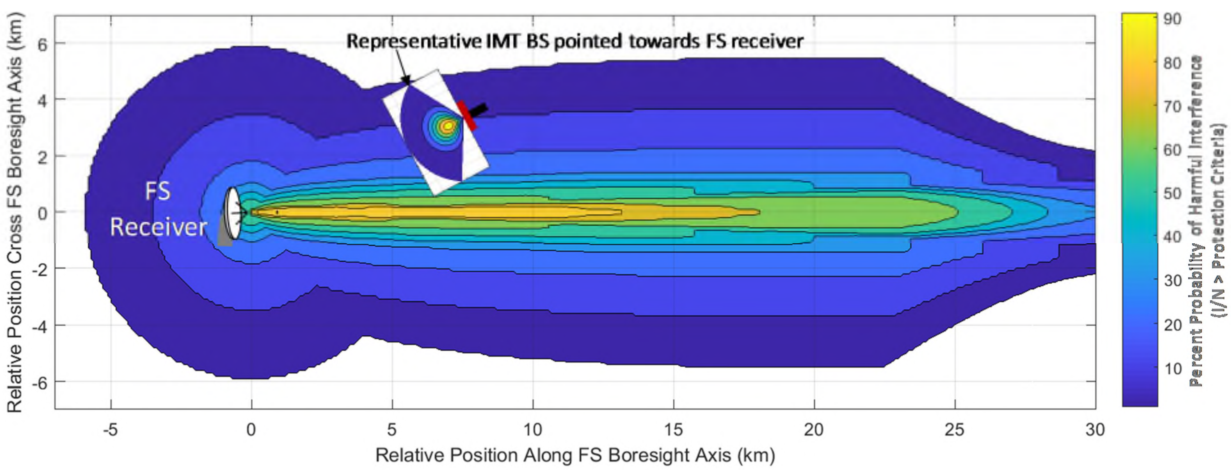

Figure 7: Percent Probability of Harmful Interference (I/N > -10 dB Protection Criterion) when IMT BS has line-of-sight and pointed in azimuth towards FS receiver

Including clutter loss, which would only be present in specific urban deployment scenarios, reduces the size of the interference region as illustrated in Figure 8 (note different scale) however the FS receivers remain sensitive to interference out to 25 km in the boresight direction which is beyond the horizon. Even for this case, the interference area is significant considering this is for a single IMT BS and much larger than the small cell IMT BS coverage distance of 100-120 meters assumed in IMT studies, and the density of base stations per km^2 may be significant, as noted below.

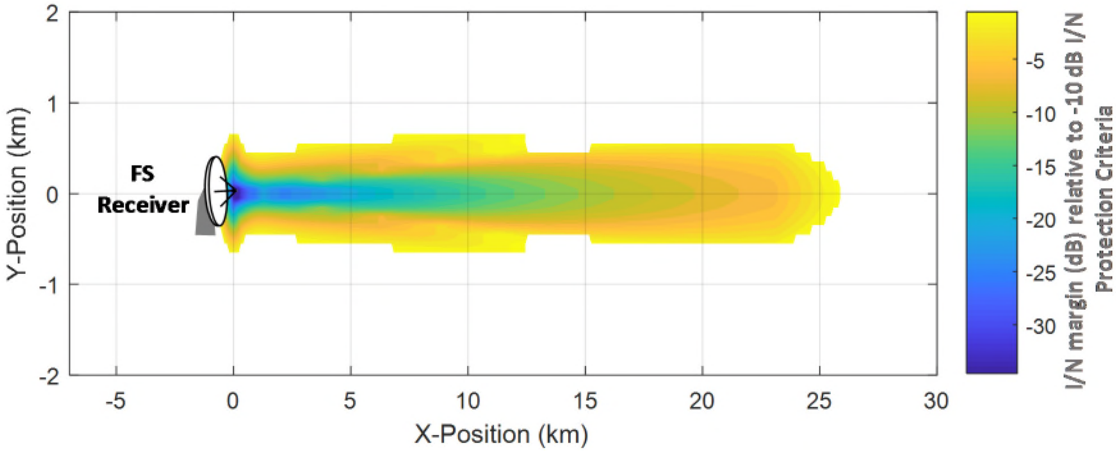

Figure 8: I/N Margin (dB) with IMT BS is pointed in azimuth towards FS receiver including clutter loss

Interference from multiple IMT BSs would result in interference level and likelihood of interference to be aggregates of the single IMT BS scenario and the overall harmful interference area would be a combination of the individual interference area.

Cumulative effects of multiple IMT BS should be considered in perspective of the ITU stated IMT densities:

- 10 BS/sq-km for Suburban hotpots (clutter assumed)
- 30 BS/sq-km for Dense Urban hotspots (clutter assumed)
- 1 BS/sq-km for Open Space hotspots (line-of-sight)

For example, in a rural area, for the line-of-sight environment with a coverage area where there is negative I/N margin relative to the Protection Criterion of 518 sq-km represented in Figure 7, there could be as many as 518 total IMT BSs deployed. Note that these figures don't even include IMT BS's outside of the depicted area which would have harmful interference areas that extend into this region. Regardless, even if the actual numbers are a small fraction of these figures and understanding that only a subset will be pointed towards the FS receiver, the potential for harmful interference is clear.

Similarly, for the clutter environment with a coverage area of 148 sq-km represented in Figure 8, in a suburban or urban environment, there could be as many as 1,480 to 4,440 IMT BS deployed with corresponding overlapping harmful interference areas. Therefore, although the interference area from a single IMT BS is much smaller than without clutter, the aggregate result could result in severe constraints on either or both IMT and FS deployments.

It should be noted that above results assume:

- IMT BS is at 6m height and FS receiver is at a 20m height
- IMT geometry and associated UE statistical distribution are per Figure 1 and Figure 3
- IMT use-case is limited to BS to UE communications

Variability in each of these factors could dramatically impact results. For example, if the IMT BS was serving users in apartment buildings, the typical pointing direction of the IMT BS electrical boresight would be upwards which could negate any assumed advantage due to clutter loss and result in much larger harmful interference areas such as that illustrated in Figure 8. The associated UE distribution would not follow the assumptions of Figure 3 and would likely result in harmful interference being concentrated in certain angles and therefore the likelihood of harmful interference in those directions would significantly increase.

STUDY RESULTS USING UMFUS BASE STATION EIRP DENSITY

The same analysis is repeated using the maximum base station EIRP density specified in the Federal Communications Commission's (FCC's) rules for UMFUS of 25 dBW/MHz (see 47 C.F.R. §30.202) for the base station instead of the -5 dBW/MHz utilized in ITU studies.

The corresponding I/N margin and probability of interference for the line-of-sight case are shown in Figure 9 using a much wider scale and illustrates large interference areas well beyond the nominal 14-16 km horizon distance shown in IMT studies. Figure 10 illustrates the impact of including clutter loss which isn't enough to overcome the 30 dB UMFUS EIRP density and results in large interference areas. Again, effects of interference from multiple base stations would be cumulative.

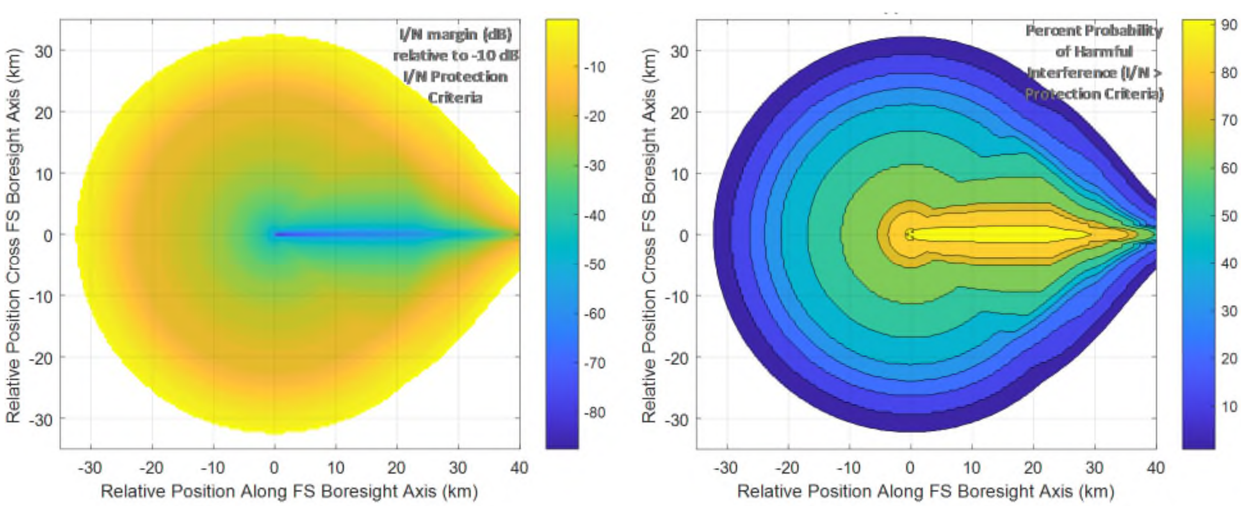

Figure 9: I/N Margin (dB) (left) and Percent Probability of Harmful Interference (right) using UMFUS maximum EIRP density when IMT BS has line-of-sight (no clutter loss) and pointed in azimuth towards FS receiver

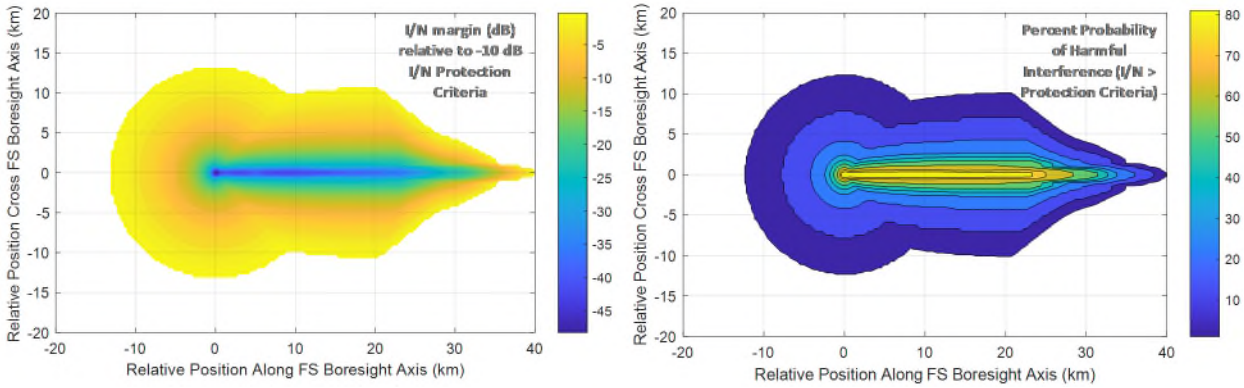

Figure 10: I/N Margin (left) and Probability of Harmful Interference (right) using UMFUS maximum EIRP density when IMT BS has line-of-sight and pointed in azimuth towards FS receiver including clutter loss

Depending on the antenna characteristics for an UMFUS base station and other operational variables, which can differ in ways that increase the potential for and level of interference into an FS receiver (for example, because of down tilts less than 10 degree and as high as horizontal, wider beam widths or installations at higher altitudes), results could well increase the potential for and degree of interference vary significantly.

As another illustration, an UMFUS base station could be located on top of a high-rise building or tower above other clutter sources with a wide beam width antenna. Since the maximum allowable EIRP density under UMFUS rules is 30 dB higher, the corresponding coverage area could be 1,000 times larger than an IMT BS nominal coverage area assuming the same IMT UEs are being served.

CONCLUSIONS

Interference from the limited scenario of a single IMT BS configured as an user access link into FS receivers can occur even at large distances of 7-30 km when line-of-sight is possible, as high gain FS receivers are sensitive to base stations aimed toward them in azimuth, even when utilizing ITU IMS BS characteristics and UE distribution statistics. Yet this is not representative of what might be the impact from UMFUS deployments, which can be deployed in numerous ways not represented in the ITU studies and with greater power, more liberal BS antenna characteristics, and other operational parameters not captured by the ITU studies.

With inclusion of clutter loss -- which may apply in some situations, such as dense urban hotspots -- the interference area decreases significantly. However, even then the FS receivers remain directionally sensitive to interference over large areas even out to 25 km from just a single base station.

Interference from multiple base stations would result in a cumulative effect to the resultant interference regions that would be significantly larger than that shown in this analysis. Given the reported IMT BS densities for various environments – ITU studies assume as many as 30 BSs per km^2 in dense urban areas.-- interference from multiple base stations could be significantly greater than that shown in this analysis.

UMFUS allowable EIRP density is nearly 30 dB higher than the IMT BS EIRP density used in ITU analyses. As a result, the resultant harmful interference area can extend out to 12-40 km from

UMFUS base stations in the same configuration even with inclusion of clutter loss and even without considering the other degrees of freedom that UMFUS users would have at their disposal beyond the limited IMT BS scenario that has been studied.

REFERENCES:

ITU-R M.2101-0 Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies

ITU-R P.2108 Prediction of Clutter Loss

ITU-R F.758-6 System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference

ITU-R F.699-7 Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

ITU-R P.452-16: Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz

ITU WP 5D/258(Rev 2): Adjacent band compatibility studies of IMT-Advanced systems in the mobile service in the band below 1 518 MHz with respect to systems in the mobile-satellite service in the frequency band 1 518-1 525 MHz

ITU 5-1/31: Reply liaison statement to Task Group 5/1 - System parameters and considerations in the development of criteria for sharing or compatibility studies

ITU 5-1/89: Liaison statement to Task Group 5/1 (copy to Working Party 4B for information) - FSS/BSS technical parameters for sharing studies under WRC-19 agenda item 1.13

Attachment B
Compatibility Analysis:
IMT BS & UMFUS Interference into
Aeronautical Mobile Service Airborne-to-Ground Link in the
25.25-27.5 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- This study assesses the compatibility with Federal Aeronautical Mobile Service (AMS) Airborne-to-Ground links which are authorized to operate in the 25.25–27.5 GHz band of possible commercial mobile Base Stations (BS) in a user access link-type configuration as envisioned in IMT-2020 studies and, then, using UMFUS permitted in-band transmissions.

- ITU IMT BS characteristics and User Equipment (UE) distribution statistics are initially utilized to determine the required separation distance between a single IMT BS and AMS Ground receiver to meet the AMS I/N Protection Criterion with and without clutter loss. The analysis is repeated using UMFUS permitted EIRP density for the base station.

- Time-variant factors, typically included in ITU statistical analyses, are not included to better represent scenarios where the local interference environment is dominated by one or more base stations.

- Study results show that even at separation distance of 15 km, AMS Ground receivers can have significant Sky Blockage exceeding 1% in line of sight situations. Clutter loss in dense urban environments reduces this distance to 1.2 km. However, even this distance is much larger than the 120 m IMT BS coverage distance, such that multiple base stations could be within a radius equal to the separation distance, as confirmed by published densities of IMT BSs. Consequently, effects on Sky Blockage from multiple IMT BS in urban environments would be cumulative and could impact or constrain one or both systems.

- Utilizing the EIRP density allowable under UMFUS, the harmful interference area (i.e. where I/N exceeds the Protection Criterion) due to a single base station for 1% Sky Blockage is beyond the horizon even when including clutter loss which, in any event, may only be present in some urban deployments.

- To improve the analysis even further, given the presumed ability of UMFUS operators to operate base stations in configurations and use cases other than the one evaluated in the ITU Studies and in this Attachment, other use cases involving less downtilt, a denser deployment of base stations, alternative UE distribution, the introduction of cross-links between base stations, and other variables could be included in future analyses.

PURPOSE OF THE STUDY

The purpose of this study is to determine the percentage of AMS Ground receiver Field of Regard is blocked at varying separation distances due to interference from IMT-2020 base stations configured to provide user access links as evaluated in the ITU studies but with modified operational and environmental assumptions and, subsequently, using UMFUS permitted EIRP density designed to represent the potential local interference environment seen by an AMS Ground receiver.

Note that there are no published ITU studies of IMT-2020 compatibility with AMS.

PARAMETERS UTILIZED FOR STUDY

Table 1 and Table 2 present IMT-2020 compatibility analysis parameters utilized for this study. Characteristics of the AMS Ground receiver utilized for this study are based on the two systems illustrated in ITU-R M.2114 and are shown in Table 3 and Table 4.

UMFUS maximum base station EIRP density of 25 dBW/MHz is based on 75 dBm/100 MHz EIRP density specified in the Federal Communications Commission's (FCC's) rules for UMFUS (see 47 C.F.R. §30.202). This study examines the effect of the higher EIRP density permitted by UMFUS rules while assuming IMT-2020 characteristics for the other parameters.

Table 1: Technical and operational characteristics of IMT-2020 systems

	Parameters from expert WPs and TG 5/1 Ad-Hoc Group	Elefante Group Study
Deployment scenario	Outdoor urban hotspot, Outdoor suburban hotspot, Outdoor suburban open space hotspot (optional), Indoor	Outdoor urban hotspot, Outdoor suburban open space hotspot
IMT stations	BS and UE	BS
Method to deploy multiple IMT stations for the aggregated interference analysis over a relatively large area (as applicable to scenarios for the studies)	**Ra and Rb method:** Ra: Urban (Outdoor): 7%, Suburban (Outdoor): 3%, Urban (Indoor) 2%, Suburban (Indoor) 1% Rb: 5%	Not applicable
Number of IMT-2020 stations	–	1 BS
Network loading factor for BS and UE (%)	20	Not applicable
TDD activity factor (%)	BS: 80, UE: 20	Not applicable
UE power control factor (dB)	Section 2.3 in Rec. ITU-R M.2101 and Items 2.2, 2.3 and 2.4 in Table 11 in Attachment 2 to Doc. 5-1/36	Not applicable
UE body loss (dB)	4	Not applicable
IMT Antenna pattern	Rec ITU-R M.2101	Rec ITU-R M.2101
Normalization of antenna gain	Additional guidance (or further clarification) is found in Annex 1 to the Chairman's Report	Not applicable
BS antenna pointing	Mechanical pointing in elevation (downtilt angle of 10°) and azimuth	10° down-tilt for the BS. BS beam points towards UEs
UE antenna pointing	Randomly in elevation in the range -90° to 90° and in azimuth in the range -60° to +60° in the direction of the BS.	Not applicable

Table 2: IMT-2020 Base Station Transmit Characteristics

Parameter	Value	Notes
Antenna Height	6m above ground level	Radiation Center
Element Gain	5 dBi	
3 dB Beamwidth of Single Element	65º	For both H/V
Front-to-Back Ratio	30 dB	For both H/V
Antenna array configuration	8x8 elements	(Row x Column)
Radiating Element Spacing	0.5 of wavelength	For both H/V
Maximum Power into Antenna	28 dBm	
Array Ohmic loss	3 dB	
Peak Antenna Gain	23 dBi	
Maximum EIRP Density	-4.9 dBW/MHz	Calculated from above

Table 3: System 1 AMS Ground Data Terminal Receive Characteristics

Parameter	Value	Source
Frequency Range	25.75 – 27.15 GHz	ITU-R M.2114-0
Channel Bandwidth	865 MHz	ITU-R M.2114-0
Rx Antenna Gain	46 dBi	ITU-R M.2114-0
Rx Antenna Beam Width	0.8 deg	Note (1)
Rx Antenna Pattern	APEREC026V01	Note (2)
Min. Elevation Angle	3 deg	Assumption
Earth Station Receiver Noise Density	-142.2 dBW/MHz	ITU-R M.2114-0, NF = 4
Protection Criterion	I/N < -6 dB	ITU-R M.2114-0

Table 4: System 2 AMS Ground Data Terminal Receive Characteristics

Parameter	Value	Source
Frequency Range	25.75 – 27.15 GHz	ITU-R M.2114-0
Channel Bandwidth	746 MHz	ITU-R M.2114-0
Rx Antenna Gain	33 dBi	ITU-R M.2114-0
Rx Antenna Beam Width	3.4 deg	Note (1)
Rx Antenna Pattern	ITU F.1245-60% efficiency	Note (2)
Min. Elevation Angle	3 deg	Assumption
Earth Station Receiver Noise Density	-141.4 dBW/Hz	ITU-R M.2114-0, NF = 4.5
Protection Criterion	I/N < -6 dB	ITU-R M.2114-0

(1) ITU-R M.2114 shows a single 7.2 deg beam width for 33 dBi and 46 dBi antennas which results in 146% - 653% antenna efficiency. Therefore, a typical 70% efficiency is used to derive beam width from the peak antenna gain.
(2) ITU-R M.2114 permits use of measured antenna pattern in lieu of ITU-R M.1851 (uniform distribution) pattern. Therefore, a standard ITU antenna pattern was selected which approximates a typical commercial antenna with similar peak gain and beam width.

STUDY SCENARIO

Figure 1 and Figure 2 illustrate the interference geometry utilized for this study.

- An IMT-2020 BS using electronic steering directs a transmit beam at maximum power towards an active UE.
- AMS Ground receiver at 6m height receives the desired signal from the AMS Airborne transmitter and receives an interfering signal from the IMT BS assumed to be operating in the same frequency band.
- As the AMS Ground tracks the Airborne transmitter, there could be portions of its 360-degree Field of Regard (FOR) over which the IMT BS antenna pointing direction, AMS Ground receiver and the Airborne transmitter are sufficiently co-aligned to result in harmful interference from the IMT BS.
- The potential harmful interference occurs over a "Cone of Interference" which subtends a solid angle representing a percentage of possible AMS Ground FOR.
- For a fixed location of the AMS Ground receiver, if a candidate IMT BS location and mechanical pointing direction of the IMT BS and the active UE location are specified, the associated range, IMT BS transmit antenna gain towards the AMS Ground receiver, and AMS Ground receive antenna gain towards the IMT BS can be utilized to determine the level of interference and compared to the AMS Ground I/N Protection Criterion.
- The IMT UE location relative to the IMT BS is defined by probability density functions (pdf's) shown in ITU WP 5D/258(Rev 2). Therefore, the resultant I/N for a specific IMT BS location is also a pdf which can be expressed as likelihood of interference to exceed the I/N Protection Criterion.
- Results from above are applicable for situations for which there is line of sight visibility (no clutter) from the IMT BS to the AMS Ground receiver.
- Impact of clutter loss on results is also examined, using parameters specified by ITU-R P.2108, to determine improvements which may be realizable in specific urban environments.
- Time-variant factors which have been used in other ITU studies are specifically not included in this study because they mask real world effects near individual base station locations. These factors include a Network Loading Factor, TDD Activity Factor and base station power division over multiple UEs. Such factors may be appropriate as part of aggregate statistical arguments applied over wide areas and long duration where impacts to specific AMS links are ignored. However, these factors may not help with mitigating against harmful interference into a specific AMS Ground receiver which is determined by the local IMT deployment environment, geometry, and use cases.

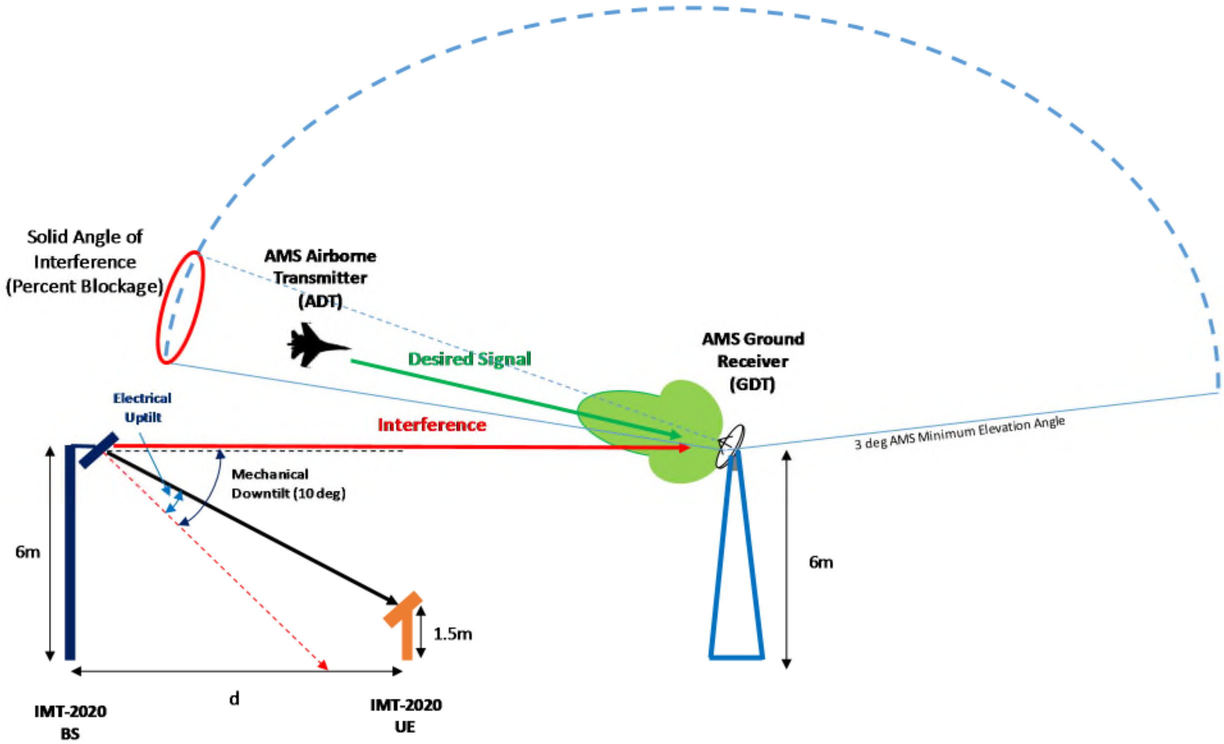

Figure 1: Interference Geometry – Elevation View

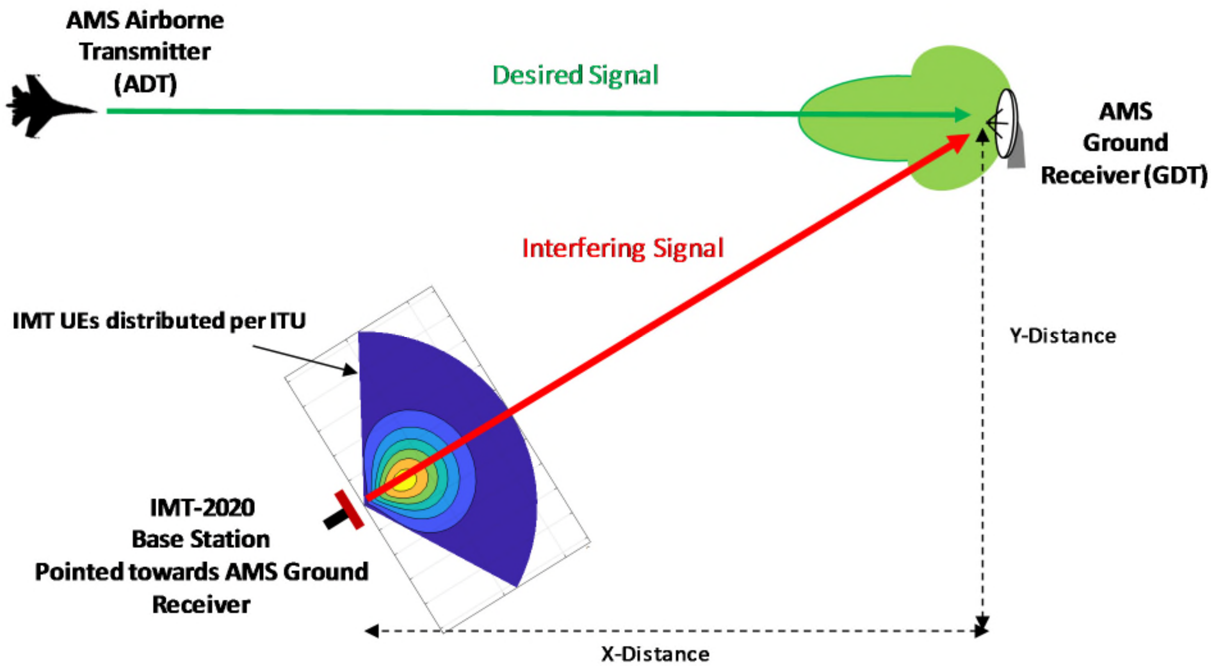

Figure 2: Interference Geometry - Plan View

STUDY METHODOLOGY

The study starts by assuming a single IMT BS is transmitting towards a single UE whose location is defined by probability density functions (pdf) as shown in Figure 3, the same as modeled in ITU studies. Specifically, the range to the UE is modeled as a Raleigh probability distribution with a characteristic value of 32 meters, and the pointing direction of the IMT BS towards the UE is defined a normal distribution function with a standard deviation of 30 deg which is clipped at 60 degrees. The combined UE pdf is also illustrated in the figure and shows that the highest concentration of UEs is modeled as being concentrated at the IMT BS boresight and within 30-50 meters of the base station and the furthest UE is 120 m away.

It should be noted that although the ITU UE distributions were utilized in this analysis, other distributions are possible and may better represent real deployment situations for flexible mobile service. Therefore, the local interference environment near a victim receiver could be significantly different with a potential for higher level of interference.

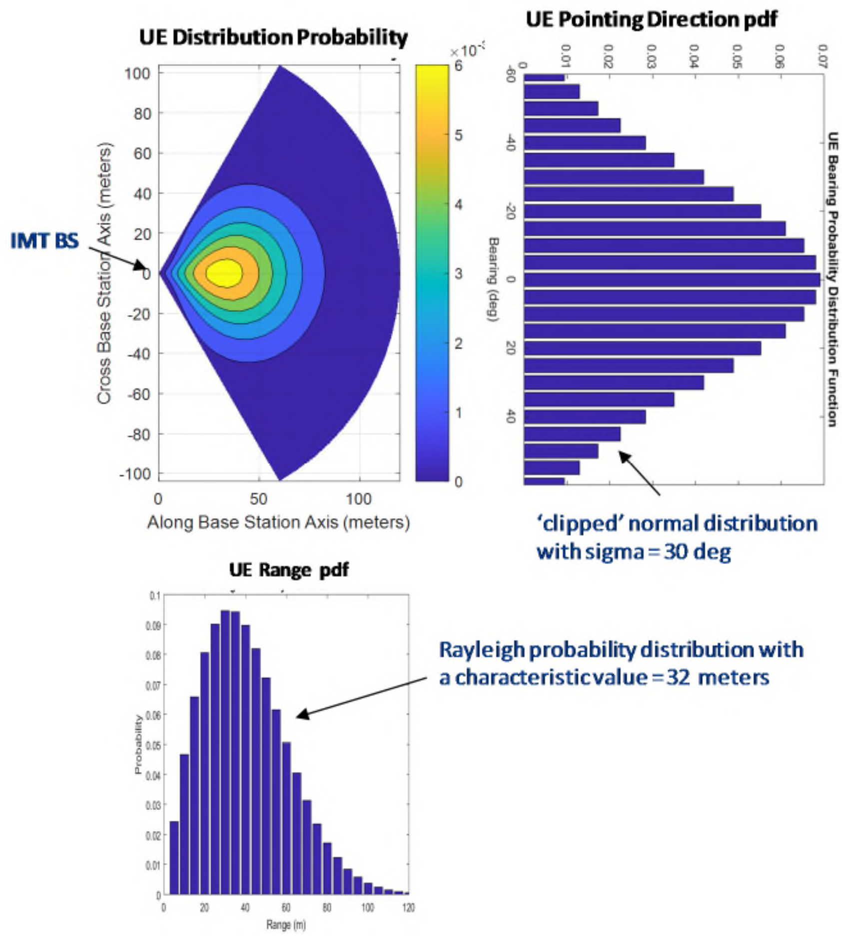

Figure 3: IMT UE distance and pointing direction probability density functions

As in ITU studies, the IMT BS antenna has its mechanical downtilt set at 10 deg while the boresight of the 8x8 array is electrically steered towards the active UE; sample antenna patters are illustrated in Figure 4.

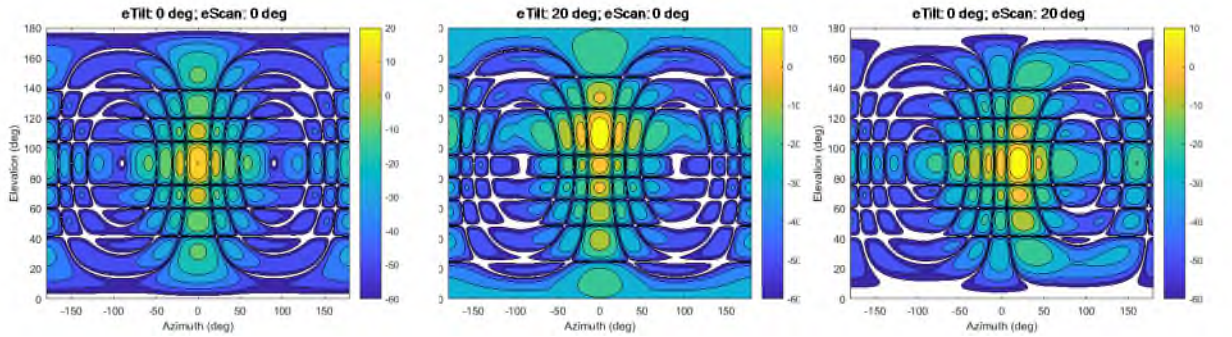

Figure 4: Sample IMT BS antenna patterns illustrating electrical steering towards the UE

To evaluate the BS EIRP towards a specific AMS Ground receiver location from various possible electrical pointing directions, a grid of UEs is first created over the IMT BS coverage area of +/- 60 degrees and range of 0-120 meters and then the corresponding IMT BS transmit antenna pattern at each grid point is determined as illustrated in Figure 5.

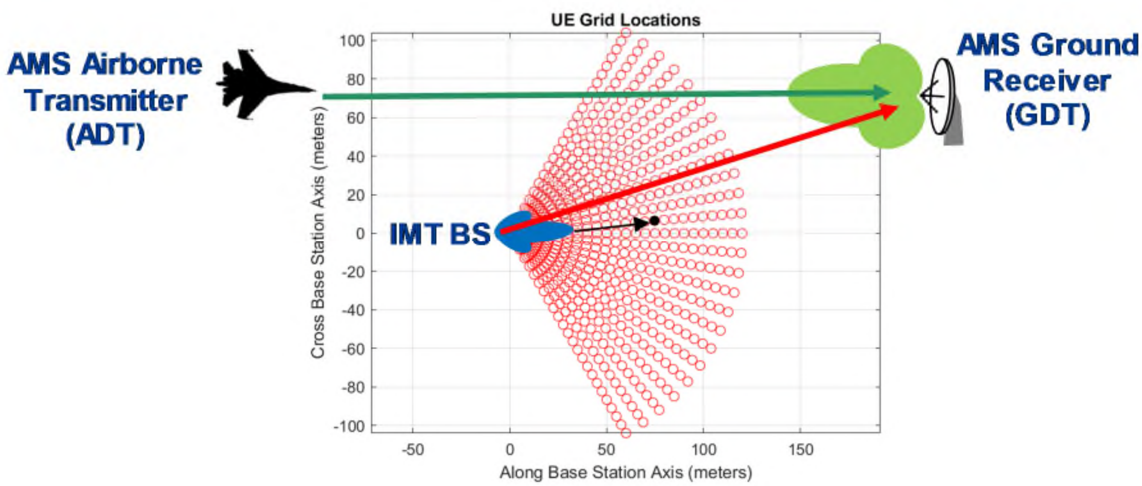

Figure 5: IMT BS EIRP towards AMS Ground Receiver is a function of electrical pointing direction towards an active UE

Since there is a pdf associated with each UE location, by extension, there is a corresponding pdf associated with each IMT BS antenna pattern.

The I/N margin relative to the AMS IN Protection Criterion of -6 dB for specific locations and pointing direction of the AMS Ground is calculated as follows:

$$Io(dBW\ /\ MHz) = EIRPDensity(\delta) - FSL - AtmLoss - Gr(\beta)$$

$$I/_N\ Margin\ (dB) = I/_N\ Threshold - (I_o - N_o)$$

where:

δ = Angle off IMT BS (Interferer) electrical boresight towards the AMS Ground receiver

$Gr\ (\beta)$ = AMS Ground Receiver (Victim) antenna gain off boresight towards IMT BS

FSL = Free Space Loss between the IMT BS and AMS Ground receiver

AtmLoss = Atmospheric loss as specified in ITU-R P.452-16 for p = 0.2

${}^{I}/_{N}\ Threshold$ is the AMS I/N Protection Criterion of -6 dB

Since δ, the angle off IMT BS (Interferer) electrical boresight, towards the AMS Ground receiver is not a fixed value but dependent on the probability associated with UE location, the probability of the I/N margin being negative is calculated from the UE probability density and the individual I/N margins at each UE location as follows:

$$Pr(INM < 0) = \sum_{UE} \Pr(UE) * H(-INM_{UE})$$

where:

$Pr(INM < 0)$ is the probability that I/N Margin (INM) is negative

$\Pr(UE)$ is the probability of a user being at a specific UE grid location

INM_{UE} is the I/N margin associated with a specific UE grid location

H( ) is the Heaviside step function or the unit step function whose value is zero for a negative argument and one for a positive argument

Since the solid angle over which harmful interference can occur is also a function of IMT BS EIRP density which is a statistical quantity, the analysis is simplified by utilizing the 90th percentile of the IMT BS EIRP density; this is a very conservative assumption favorable to the IMT BS operator since it approximately represents 10% likelihood of harmful interference which is much higher than typical quality of service requirements which are usually <<1%. In other words, this assumption gives benefit to the IMT BS interferer in assuming that actual performance will not be as bad as assuming the 100% worst-case situation.

The received interference power density can now be subtracted from the receive noise power density and compared to the -6 dB I/N Protection Criterion to determine the minimum AMS Ground receive antenna gain required to meet the I/N Protection Criterion.

Utilizing the AMS Ground receive antenna pattern, the minimum AMS Ground receive antenna gain is then converted to the angle over which interference would exceed the I/N Protection Criterion, and thus be considered harmful. Since the AMS Ground receive antenna pattern is symmetric about its boresight, the interference angle is converted into a Solid Angle of Interference (SAI).

The possible FOR of AMS Ground is calculated by assuming 360-degree azimuth coverage and a minimum elevation angle of 3 degrees and assuming no other blockage from structures or terrain.

The percent of FOR over which interference exceeds the I/N Protection Criterion "Sky Blockage" and is thus harmful is calculated as follows:

$$\%\ Sky\ Blockage = \frac{SAI\ (Solid\ Angle\ of\ Interference)}{FOR\ (Field\ of\ Regard)} * 100$$

The % Sky Blockage is calculated for varying relative locations of AMS Ground receivers and IMT BS in the reference frame of the IMT BS.

The analysis is repeated with inclusion of clutter loss using the ITU-R P.2108 model with 1% location probability, to represent the outdoor urban hotspot environment.

The analysis is also repeated with the 30 dB higher UMFUS EIRP density in contrast with the relatively benign EIRP density used in the ITU studies. Other UMFUS use cases such as with varying base station downtilt, beam width, antenna heights, antenna pattern and UE distribution have not yet been studied, but would be recommended for future studies since they would be expected to potentially present greater incidence of harmful interference and at greater distances alone and in combination.

STUDY RESULTS

Figure 6 illustrates the percent Sky Blockage for AMS System 1 for varying locations of the AMS Ground relative to the IMT BS for a line of sight situation using the IMT customer access link scenario. Results indicate that there is a large keep out area around the IMT BS which extends nearly to the horizon of 14-16 km, over which the Sky Blockage is greater than 1%. The yellow colored area extends out to 3 km which indicates greater than 10% Sky Blockage. As reference, the percent sky subtended by the sun is approximately 0.001%.

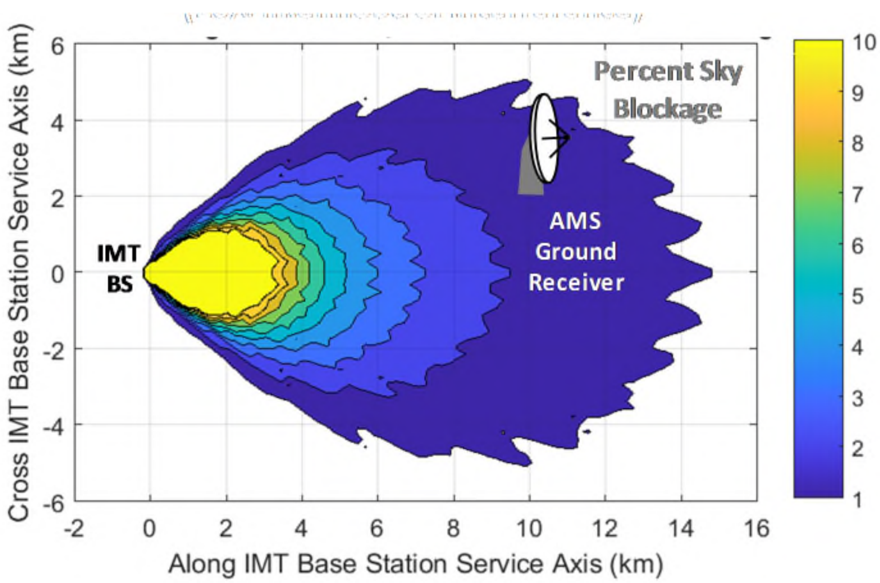

Figure 6: AMS System 1 Percent Sky Blockage vs AMS Ground receiver location in IMT BS frame assuming Line of Sight (without clutter loss)

Including clutter loss, which would only be present in specific urban deployment scenario, reduces the size of the potentially harmful interference region as shown in Figure 7. However, the Sky Blockage exceeds 1% out to 1.2 km in front of the IMT BS and exceeds 10% 0.5 km in front of the IMT BS, which is much larger than the small cell IMT BS coverage distance of 100-120 meters assumed in IMT studies, and the density of base stations per km^2 may be significant, as noted below.

Interference from multiple IMT BS would result in a cumulative effect in that the percent Sky Blockage would be the aggregate of the single IMT BS scenario and the overall harmful interference area would be a combination of the individual interference areas.

Cumulative effects of multiple IMT BSs should be considered in perspective of the ITU stated IMT densities:

- 10 BS/sq-km for Suburban hotpots (clutter assumed)
- 30 BS/sq-km for Dense Urban hotspots (clutter assumed)
- 1 BS/sq-km for Open Space hotspots (line of sight)

Very similar results were obtained for System 2 as shown in Figure 8 and Figure 9.

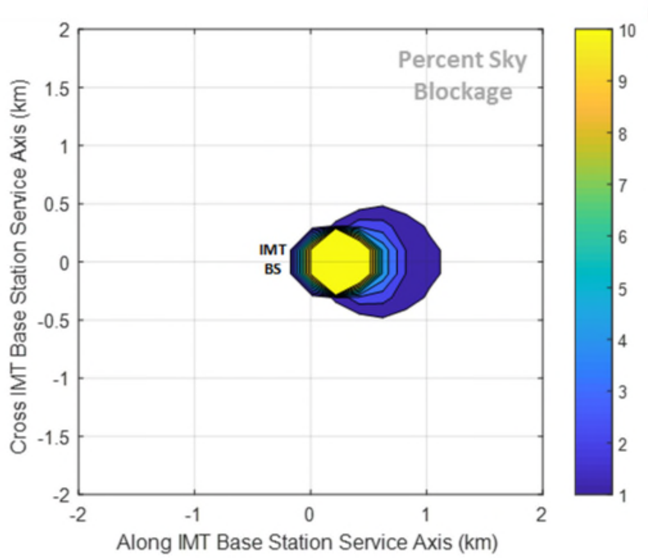

Figure 7: AMS System 1 Percent Sky Blockage vs AMS Ground receiver location in IMT BS frame Including clutter loss

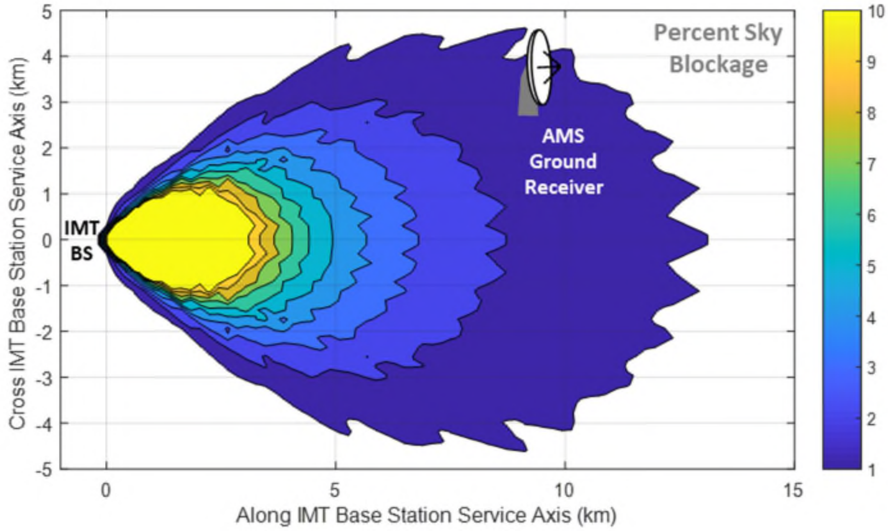

Figure 8: AMS System 2 Percent Sky Blockage vs AMS Ground receiver location in IMT BS frame assuming Line of Sight (without clutter loss)

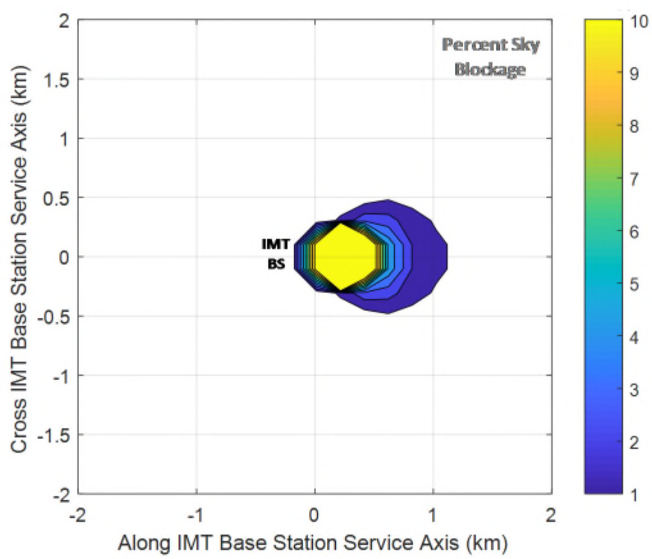

Figure 9: AMS System 2 Percent Sky Blockage vs AMS Ground receiver location in IMT BS frame Including clutter loss

It should be noted that above results assume:

- IMT-BS and AMS Ground receiver are both at 6m height
- IMT geometry and associated UE statistical distribution are per Figure 1and Figure 3
- IMT use-case is limited to BS to UE communications

Variability in each of these factors could dramatically impact results. For example, if the AMS Ground is located outside the IMT coverage area in a direction where there is a concentration of UEs due to local conditions, the likelihood of interference and therefore the Sky Blockage would increase. Similarly, if the IMT BS was located on a hill serving users below, there may be direct line of site interference into the AMS Ground receiver resulting in greater level of interference.

STUDY RESULTS USING UMFUS BASE STATION EIRP DENSITY

The same analysis is repeated using the maximum base station EIRP density specified in the Federal Communications Commission's (FCC's) rules for UMFUS of 25 dBW/MHz (see 47 C.F.R. §30.202) instead of the -5 dBW/MHz utilized in ITU studies.

The corresponding Sky Blockage for the line of sight case is shown in Figure 10 using a much wider distance and Sky Blockage scale. Results indicate greater than 90% Sky Blockage at very large distances out to 16 km, beyond the nominal 14-16 km horizon distance. 1% Sky Blockage fans out to 15 km at +/- 90 degrees and is over 25 km in front of the IMT BS.

Inclusion of clutter loss, as illustrated in Figure 11, is not enough to overcome the 30 dB higher UMFUS EIRP density and results in large areas out to the horizon where the sky blockage is greater than 1%. Again, effects of interference from multiple base stations would be cumulative.

Depending on the antenna characteristics for an UMFUS base station, and other operational variables, which can differ in ways that increases the potential for and level of interference into an AMS Ground receiver (for example, because of base station downtilt less than 10 degree and as high as horizontal, wider beam widths or installations at higher altitudes), results could well increase the potential for and area of harmful interference very significantly.

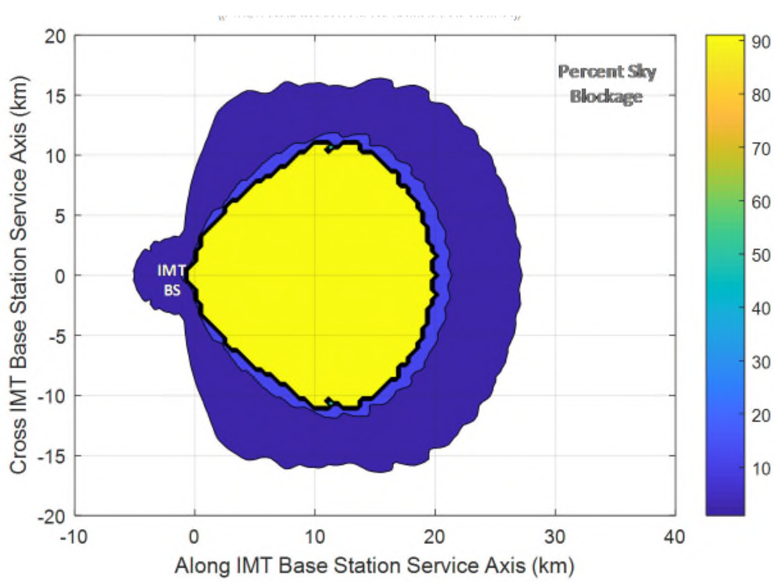

Figure 10: AMS System 1 Percent Sky Blockage vs AMS Ground receiver location in BS frame using UMFUS maximum EIRP density assuming Line of Sight (without clutter loss)

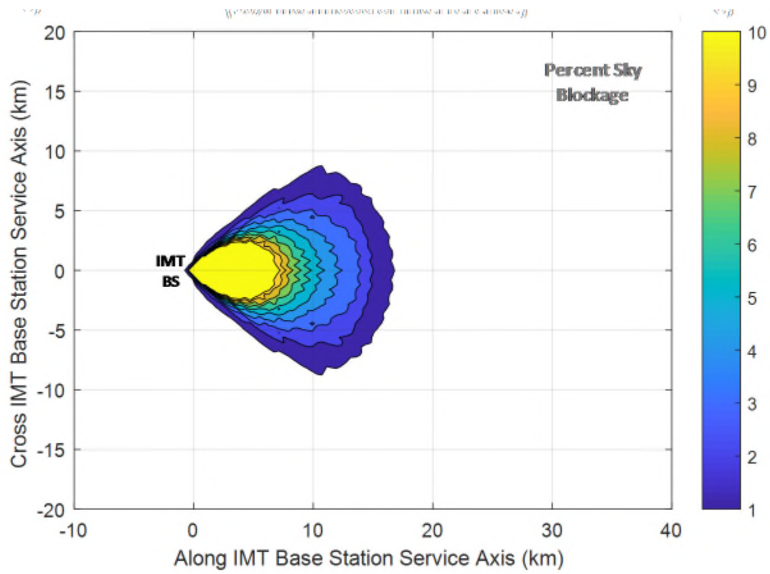

Figure 11: AMS System 1 Percent Sky Blockage vs AMS Ground receiver location in BS frame using UMFUS maximum EIRP density including Clutter Loss

CONCLUSIONS

Interference from the limited scenario of a single IMT BS configured as a user access link into AMS Ground receivers can result in significant Sky Blockage exceeding 1% out to a separation distance of 15 km when line of sight is possible, even when utilizing ITU IMS BS characteristics and UE distribution statistics. Yet this is not representative of what might be the impact from UMFUS, which can be deployed in numerous ways not represented in the ITU studies and with greater power, more liberal BS antenna characteristics, and other operational parameters not captured by the ITU studies.

With inclusion of clutter loss -- which will apply in some situations, such as dense urban hotspots -- the harmful interference zones decrease notably. However, the AMS Ground receiver's Sky Blockage is still 1% out to 1.2 km in front of the IMT BS and at lesser, but still a significant distance particularly when considering the quantity of base stations, each with a 120-meter coverage area, could be present. Sky Blockage exceeds 10%, 0.5 km in front of the IMT BS.

Interference from multiple base stations would result in a cumulative effect to the resultant interference regions that would be significantly larger than that shown in this analysis. Given the reported IMT BS densities for various environments – ITU studies assume as many as 30 BSs per km^2 in dense urban areas.-- interference from multiple base stations could be significantly greater than that shown in this analysis.

Percentage Sky Blockage using the nearly 30 dB higher UMFUS EIRP density than the IMT BS EIRP density used in ITU analyses are shown in Figure 10 and Figure 11. Even with inclusion of clutter loss, large separation distances of up to 16 km are required to avoid harmful interference at a 1% Sky Blockage level when all other parameters are the same. Where the assumption of clutter loss is not justified, the 10% sky blockage extends to near the horizon, and the 1% Sky Blockage extends to at least 15 km over a 180-degree arc and up to 25 km in front of the IMT BS. These results exist even without considering the other degrees of freedom that UMFUS users would have at their disposal beyond the limited IMT BS scenario and UMFUS power levels that have been studied.

REFERENCES:

ITU-R M. 2114-0: Technical and operational characteristics of and protection Criterion for aeronautical mobile service systems in the frequency bands 22.5-23.6 GHz and 25.25-27.5 GHz

ITU-R F.1245-2: Mathematical model of average and related radiation patterns for line-of-sight point-to-point fixed wireless system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz

APEREC026V01: Recommendation ITU-R S.465-6 Receiving reference Earth station antenna pattern for earth stations in FSS in the frequency range from 2 to 31 GHz coordinated after 1993.

ITU-R M.2101-0 Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies

ITU-R P.2108 Prediction of Clutter Loss

ITU-R F.758-6 System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference

ITU-R F.699-7 Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

ITU-R P.452-16: Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz

ITU WP 5D/258(Rev 2): Adjacent band compatibility studies of IMT-Advanced systems in the mobile service in the band below 1 518 MHz with respect to systems in the mobile-satellite service in the frequency band 1 518-1 525 MHz

ITU 5-1/31: Reply liaison statement to Task Group 5/1 - System parameters and considerations in the development of criteria for sharing or compatibility studies

ITU 5-1/89: Liaison statement to Task Group 5/1 (copy to Working Party 4B for information) - FSS/BSS technical parameters for sharing studies under WRC-19 agenda item 1.13

Attachment C
Compatibility Analysis:
IMT BS & UMFUS BS Interference into SBCS User Terminals in the 25.25-27.5 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- Elefante Group is proposing that Stratospheric-Based Communications Service (SBCS) access the 25.25–27.5 GHz band for User downlink communications from Stratospheric Platform Stations (STRAPS) to User Terminals (UTs) on a co-Primary basis.

- This study assesses the compatibility with SBCS user downlinks to UTs in the 25.25-27.5 GHz band of possible commercial mobile Base Stations (BS) in a user access link-type configuration as envisioned in IMT-2020 studies and, then extends the analysis using UMFUS permitted in-band transmissions.

- ITU IMT BS characteristics and User Equipment (UE) distribution statistics are initially utilized to determine the required separation distance between a single IMT BS and SBCS UTs to meet the proposed SBCS I/N Protection Criterion with and without clutter loss. The analysis is repeated using UMFUS permitted EIRP density for the base station.

- Time-variant factors, typically included in ITU statistical analyses, are not included to better represent scenarios where the local interference environment is dominated by one or more base stations.

- Study results show that, even at a separation distance of 1.2 km, a single IMT BS in line-of-sight environments can cause harmful interference (i.e. I/N exceeds the Protection Criterion) into an SBCS UT independent of UT pointing direction and elevation angle. Clutter loss in dense urban environments reduces this distance to 0.4 km which is still more than three times the 120 m coverage distance of a single IMT hotspot. Interference from multiple IMT BS would be cumulative and, considering published densities of IMT BS, could severely constraint one or both systems.

- Utilizing the EIRP density allowable under UMFUS, the harmful interference area due to a single base station is beyond the horizon when there is clear line of sight and still 0.5-4.3 km even with inclusion of clutter loss which, in any event, may only be present in some urban deployments.

- To improve the analysis even further, given the presumed ability of UMFUS operators to operate base stations in configurations and use cases other than the one evaluated in the ITU Studies and in this Attachment, other use cases involving less base station downtilt, a denser deployment of base stations, alternative UE distributions, the introduction of cross-links between base stations, and other variables could be included in the future.

PURPOSE OF THE STUDY

The purpose of this study is to determine likelihood of harmful interference at varying separation distances from IMT-2020 base stations configured to provide user access links as evaluated in ITU studies but with modified operational and environmental assumptions and, subsequently, using UMFUS permitted EIRP density, designed to represent the potential local interference seen by SBCS UTs.

PARAMETERS UTILIZED FOR STUDY

Table 1 and Table 2 present IMT-2020 compatibility analysis parameters utilized for this study. Table 3 shows Elefante Group SBCS & Enterprise and Consumer UT receive characteristics.

UMFUS maximum base station EIRP density of 25 dBW/MHz is based on 75 dBm/100 MHz EIRP density specified in the Federal Communications Commission's (FCC's) rules for UMFUS (see 47 C.F.R. §30.202). This study examines the effect of the higher EIRP density permitted by UMFUS rules while assuming IMT-2020 characteristics for the other parameters.

Table 1: Technical and operational characteristics of IMT-2020 systems

	Parameters from expert WPs and TG 5/1 Ad-Hoc Group	Elefante Group Study
Deployment scenario	Outdoor urban hotspot, Outdoor suburban hotspot, Outdoor suburban open space hotspot (optional), Indoor	Outdoor urban hotspot, Outdoor suburban open space hotspot
IMT stations	BS and UE	BS
Method to deploy multiple IMT stations for the aggregated interference analysis over a relatively large area (as applicable to scenarios for the studies)	**Ra and Rb method:** Ra: Urban (Outdoor): 7%, Suburban (Outdoor): 3%, Urban (Indoor) 2%, Suburban (Indoor) 1% Rb: 5%	Not applicable
Number of IMT-2020 stations	–	1 BS
Network loading factor for BS and UE (%)	20	Not applicable
TDD activity factor (%)	BS: 80, UE: 20	Not applicable
UE power control factor (dB)	Section 2.3 in Rec. ITU-R M.2101 and Items 2.2, 2.3 and 2.4 in Table 11 in Attachment 2 to Doc. 5-1/36	Not applicable
UE body loss (dB)	4	Not applicable
IMT Antenna pattern	Rec ITU-R M.2101	Rec ITU-R M.2101
Normalization of antenna gain	Additional guidance (or further clarification) is found in Annex 1 to the Chairman's Report	Not applicable
BS antenna pointing	Mechanical pointing in elevation (downtilt angle of 10°) and azimuth	10° down-tilt for the BS. BS beam points towards UEs
UE antenna pointing	Randomly in elevation in the range -90° to 90° and in azimuth in the range -60° to +60° in the direction of the BS.	Not applicable

Table 2: IMT-2020 Base Station Transmit Characteristics

Parameter	Value	Notes
Antenna Height	6m above ground level	Radiation Center
Element Gain	5 dBi	
3 dB Beamwidth of Single Element	65º	For both H/V
Front-to-Back Ratio	30 dB	For both H/V
Antenna array configuration	8x8 elements	(Row x Column)
Radiating Element Spacing	0.5 of wavelength	For both H/V
Maximum Power into Antenna	28 dBm	
Array Ohmic loss	3 dB	
Peak Antenna Gain	23 dBi	
Maximum EIRP Density	-4.9 dBW/MHz	Calculated from above

Table 3: Elefante Group SBCS & User Terminal Receive Characteristics

Parameter	Units	Value	
UT Category		Consumer (Narrowband)	Enterprise (Fullband)
RX Band	GHz	25.25-27.5	25.25-27.6
Bandwidth	MHz	5 to 20	450
Aperture Diameter	m	0.45	1
Boresight Gain	dBi	34	40.7
3dB Beam width	deg	3.35	1.6
Pattern		ITU-R F.1245-2	ITU-R F.1245-2
Polarization		RHCP/LHCP	RHCP/LHCP
Max Elevation Angle	deg	90	90
Min Elevation Angle	deg	12.5-16.6	12.5-16.6
Height above ground	m	10 typical	10 typical
Receiver Noise Density	dB(W/MHz)	-141.7	-141.7
Protection Criteria (I/N) - Inter-FS	dB	-6	-6
Protection Criteria (I/N) - Intra-FS	dB	-10	-10
Nominal Platform Service Radius	km	70	
Min Platform Altitude	km	18.3	
Max Platform Altitude	km	21.3	
Max Platform Flight Radius	km	10	

STUDY SCENARIO

Figure 1 illustrates the interference geometry utilized for this study.

- An IMT-2020 BS using electronic steering directs a transmit beam at maximum power towards an active UE.
- An SBCS UT at 6 m height receives the desired signal from the STRAPS and receives an interfering signal from the IMT BS assumed to be operating in the same frequency band. For Consumer UTs, since the SBCS channel bandwidth of 5-20 MHz is much narrower than the IMT 200 MHz bandwidth, it is assumed that interference is received across the entire UT channel bandwidth. Since the channel bandwidth of Enterprise UTs is up to 450 MHz and the likelihood of a specific UE using two adjacent 200 MHz bands is not clear, it is assumed that only 200 MHz out of a 450 MHz UT channel bandwidth will receive interference.
- For a fixed location of the SBCS UT, if a candidate location and mechanical pointing direction of the IMT BS and the active UE location are specified, the associated range, IMT BS transmit antenna gain towards the SBCS UT, and SBCS UT receive antenna gain towards the IMT BS can be utilized to determine the level of interference and compared to the SBCS I/N Protection Criterion.
- Since the SBCS UT antennas have narrow beams which are directed upwards to the STRAPS with a minimum elevation angle of 15 degrees, the analysis is made simpler since the SBCS UT receive antenna gain towards the IMT BS is constant across all azimuth angles and for all applicable UT elevation angles from 15 to 90 degrees.
- The IMT UE location relative to the IMT BS is defined by probability density functions (pdf) shown in ITU WP 5D/258(Rev 2). Therefore, the resultant I/N for a specific IMT BS location is also a pdf which can be expressed as likelihood of interference to exceed the I/N Protection Criterion.
- Results from above are applicable for situations for which there is line of sight visibility from the IMT BS to the SBCS UT.
- Impact of clutter loss on results is also examined, using parameters specified by ITU-R P.2108, to determine improvements which may be realizable in specific urban environments in certain situations.
- Time-variants factors which have been used in other ITU studies are specifically not included in this study because they mask real world effects near individual base station locations. These factors include a Network Loading Factor, TDD Activity Factor and base station power division over multiple UEs. Such factors may be appropriate as part of aggregate statistical arguments applied over wide areas and long duration where impacts to specific FS links are ignored. However, these factors may not help with mitigating against harmful interference into a specific SBCS UT which is determined by the local IMT deployment environment, geometry, and use cases.

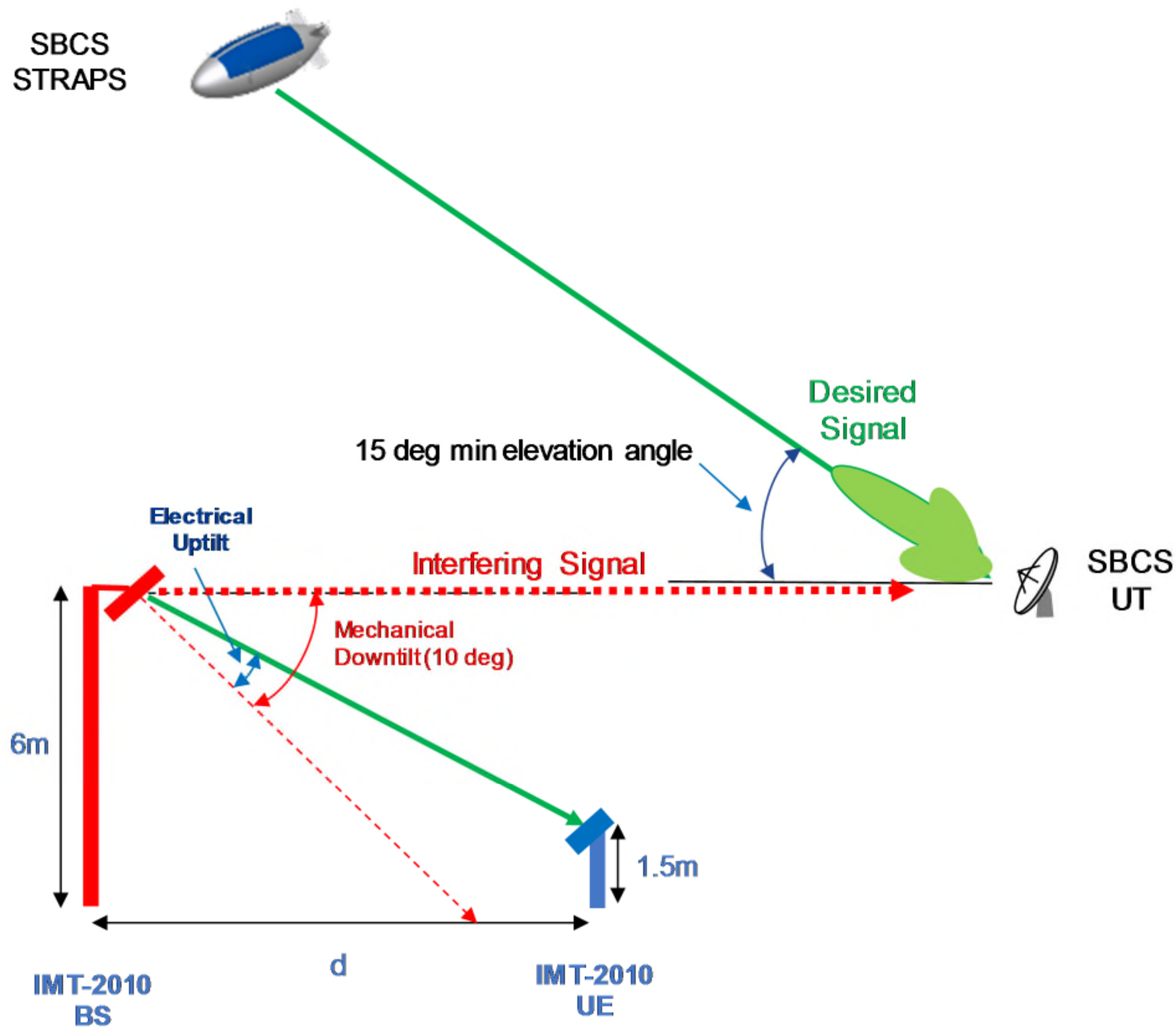

Figure 1: Interference Geometry – Elevation View

STUDY METHODOLOGY

The study starts by assuming a single IMT BS is transmitting towards a single IMT UE whose location is defined by pdf's as shown in Figure 2, the same as modeled in ITU studies. Specifically, the range to the UE is modeled as a Raleigh probability distribution with a characteristic value of 32 meters and the pointing direction of the IMT BS towards the UE is defined a normal distribution function with a standard deviation of 30 deg which is clipped at 60 degrees. The combined UE pdf is also illustrated in the figure and shows that the highest concentration of UEs is modeled as being concentrated at the base station boresight and within 30-50 meters of the IMT BS and the furthest UE is 120 m away.

It should be noted that although the ITU UE distributions were utilized in this analysis, other distributions are possible and may better represent real deployment situations for flexible mobile service. Therefore, the local interference environment near a victim receiver could be significantly different with a potential for higher level of interference.

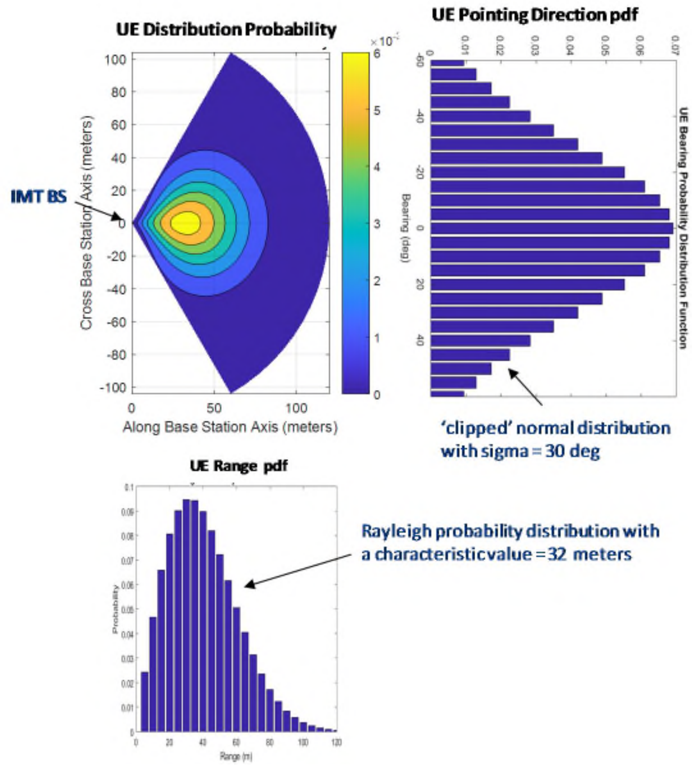

Figure 2: IMT UE distance and pointing direction probability density functions

As in ITU studies, the IMT BS antenna has its mechanical downtilt set at 10 deg while the boresight of the 8x8 array is electrically steered towards the active UE; sample antenna patterns are illustrated in Figure 3.

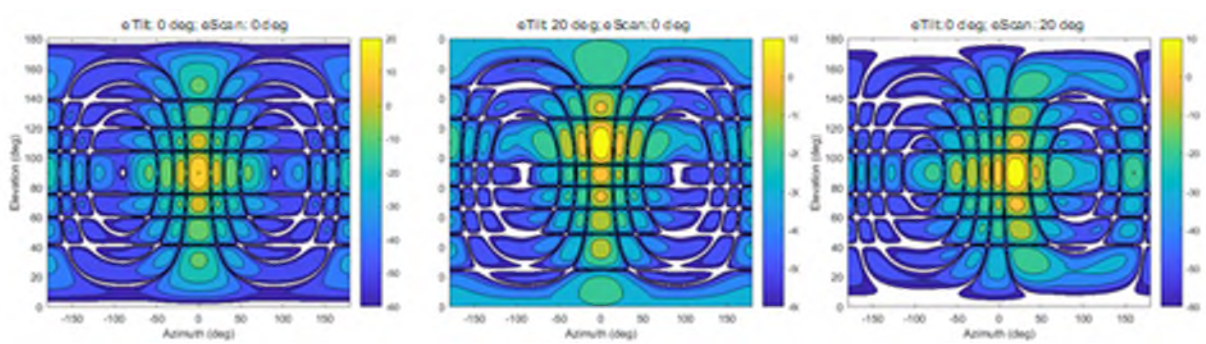

Figure 3: Sample IMT BS antenna patterns illustrating electrical steering towards the UE

To evaluate the IMT BS EIRP towards a specific SBCS UT location from various possible electrical pointing directions, a grid of UEs is first created over the IMT BS coverage area of +/- 60 degrees and range of 0-120 meters and then the corresponding IMT BS transmit antenna pattern at each grid point is determined as illustrated in Figure 4.

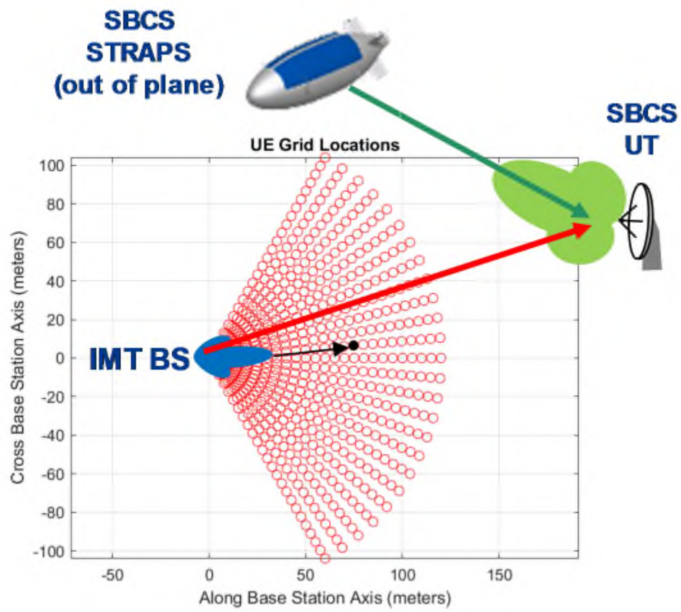

Figure 4: IMT BS EIRP towards SBCS UT receiver is a function of electrical pointing direction towards an active UE

Since there is a pdf associated with each UE location, by extension, there is a corresponding pdf associated with each IMT BS antenna pattern.

The I/N margin relative to the SBCS I/N Protection Criterion of -10 dB for specific locations of the SBCS UT is calculated as follows:

$$Io(dBW / MHz) = EIRPDensity(\delta) - FSL - AtmLoss - Gr(\beta) \text{ - BWR (dB) – PolLoss}$$

$$I/_N \ Margin\ (dB) = I/_N \ Threshold - (I_o - N_o)$$

where:

δ = Angle off IMT BS (Interferer) electrical boresight towards the SBCS UT

$Gr\ (\beta)$ = SBCS UT (Victim) antenna gain in dB off boresight towards IMT BS which is a constant value based on antenna sidelobe performance since the beam is pointed towards the SBCS STRAPS with a minimum elevation angle of 15 degrees

FSL = Free Space Loss in dB between the IMT BS and SBCS UT

AtmLoss = Atmospheric loss in dB as specified in ITU-R P.452-16 for p = 0.2

BWR = For Enterprise UTs, Bandwidth Ratio in dB is the ratio of IMT channel bandwidth and UT channel bandwidth (450 MHz / 200 MHz). For Consumer UTs, BWR is 1 since UT channel bandwidth is much narrower than IMT channel bandwidth

PolLoss = Polarization loss in dB of 1.5 dB, 3.0 dB to account for circular polarization of SBCS user link versus linear polarization of the IMT link adjusted down by 1.5 dB since UT reception is in the back lobe and to account for geometric misalignments.

$^{I}/_{N}$ $Threshold$ is the SBCS I/N Protection Criterion of -10 dB

Since δ, the angle off IMT BS (Interferer) electrical boresight, towards the SBCS UT is not a fixed value but dependent on the probability associated with UE location, the probability of the I/N margin being negative is calculated from the UE probability density and the individual I/N margins at each UE location as follows:

$$Pr(INM < 0) = \sum_{UE} \Pr(UE) * H(-INM_{UE})$$

where:

$Pr(INM < 0)$ is the probability that I/N Margin (INM) is negative

$\Pr(UE)$ is the probability of a user being at a specific UE grid location

INM_{UE} is the I/N margin associated with a specific UE grid location

H( ) is the Heaviside step function or the unit step function whose value is zero for a negative argument and one for a positive argument

The absolute I/N margin and the probability of negative I/N margin is calculated for varying relative locations of SBCS UT and IMT BS in the reference frame of the IMT BS.

The analysis is repeated with inclusion of clutter loss using the ITU-R P.2108 model with 1% location probability, to represent the outdoor urban hotspot environment.

The analysis is also repeated with the 30 dB higher UMFUS EIRP density in contrast with the relatively benign EIRP density used in the ITU studies. Other UMFUS use cases such as with varying base station downtilt, beam width, antenna heights, antenna pattern and UE distribution have not yet been studied but would be recommended for future studies since they would be expected to potentially present greater incidence of harmful interference and at greater distances alone and in combination.

STUDY RESULTS

Figure 5 illustrates the percent probability of I/N margin exceeding the -10 dB I/N Protection Criterion for varying locations of SBCS Enterprise and Consumer UTs around the IMT BS having line of sight to the IMT BS using the IMT customer access link scenario. The minimum separation distance for Enterprise UTs at the IMT BS boresight is 1.1 km where the probability of harmful interference is 1% and 0.6 km for a probability of harmful interference of 10%, well beyond the typical Quality of Service needs of <<0.1%. Consumer UTs are more susceptible since unlike Enterprise UTs with a channel bandwidth of 450 MHz, the Consumer UT channel bandwidth is narrower than the IMT channel bandwidth of 200 MHz Therefore, the full bandwidth of a Consumer UT is assumed to receive the interference. For Enterprise UTs, if multiple adjacent IMT channels are active, so as to fill the entire Enterprise UT channel bandwidth, then interference levels would be greater than depicted in this analysis.

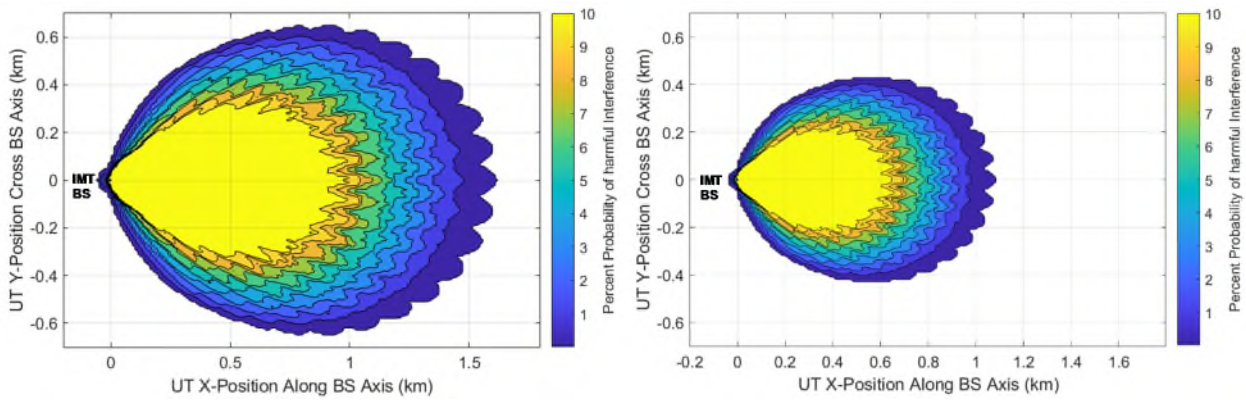

Figure 5: Percent Probability of Harmful Interference (I/N > -10 dB Protection Criterion) for Consumer UT (Left) and Enterprise UT (Right) – Assuming Line of Sight (no clutter loss)

Including clutter loss, which would only be present in specific urban deployment scenarios, reduces the size of the harmful interference region as illustrated in Figure 6 (note different scale). However, the harmful interference area for 1% probability is still 0.3-0.4 km in the IMT BS boresight direction and several times larger than the small cell IMT BS coverage distance of 100-120 meters assumed in IMT studies, and the density of base stations per km^2 may be significant, as noted below.

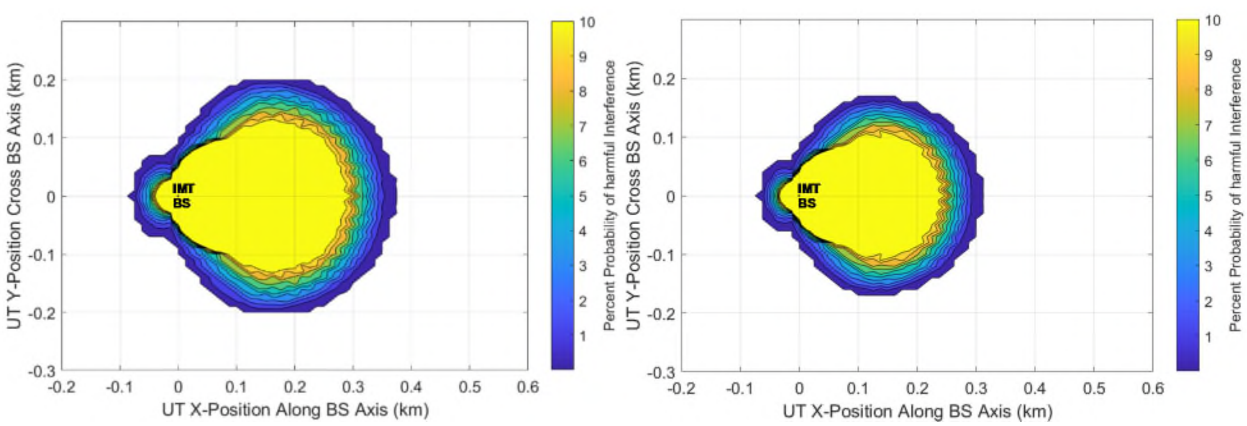

Figure 6: Percent Probability of Harmful Interference (I/N > -10 dB Protection Criterion) for Consumer UT (Left) and Enterprise UT (Right) - including Clutter Loss representing dense urban environments

It should be noted that above results assume:

- IMT BS and SBCS UT are both at 6 m heights
- IMT geometry and associated UE statistical distribution is per Figure 1 and Figure 2
- IMT use case is limited to BS to UE communications

Variability in each of these factors could dramatically impact results. For example, if the UE bearing direction distribution is assumed to be uniform probability instead of Rayleigh probability as assumed in IMT studies, the likelihood of harmful interference increases to nearly 10% in most of the area as illustrated by the yellow colored zone in Figure 7.

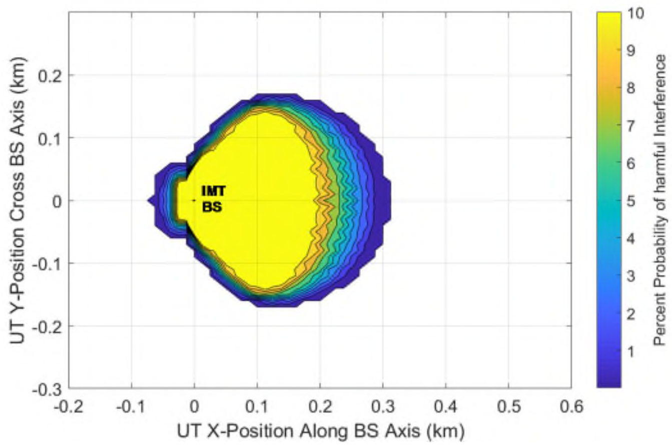

Figure 7: Percent Probability of Harmful Interference (I/N > -10 dB Protection Criterion) for Enterprise UT - including Clutter Loss, with uniform IMT UE bearing distribution

Similarly, if the IMT-BS was serving users in apartment buildings, the typical pointing direction of the IMT BS electrical boresight would be upwards which could negate any assumed advantage due to clutter loss and result in much larger harmful interference areas such as that illustrated in Figure 5. The associated UE distribution would not follow the assumptions of Figure 4 and would likely result in harmful interference being concentrated in certain angles and therefore the likelihood of harmful interference in those directions would significantly increase.

Interference from multiple BS would result in a cumulative effect to the resultant harmful interference regions that would be significantly greater than that shown in this analysis. Such cumulative effects of multiple IMT BSs should be considered in perspective of the ITU stated IMT densities:

- 10 BS/sq-km for Suburban hotpots (clutter assumed)
- 30 BS/sq-km for Dense Urban hotspots (clutter assumed)
- 1 BS/sq-km for Open Space hotspots (line of sight)

STUDY RESULTS USING UMFUS BS EIRP DENSITY

The same analysis is repeated using the maximum base station EIRP density specified in the Federal Communications Commission's (FCC's) rules for UMFUS of 25 dBW/MHz (see 47 C.F.R. §30.202) instead of the -5 dBW/MHz utilized in ITU studies, keeping other IMT operational variables the same.

The corresponding probability of harmful interference into Consumer UTs is shown in Figure 8 which illustrates large harmful interference areas well beyond the nominal 14-16 km horizon distance for the direct line of sight case. Including clutter loss reduces the harmful interference area. However, there is still a large harmful interference area extending out to 3.5 km in front of the BS and 0.5 km even directly behind the base station.

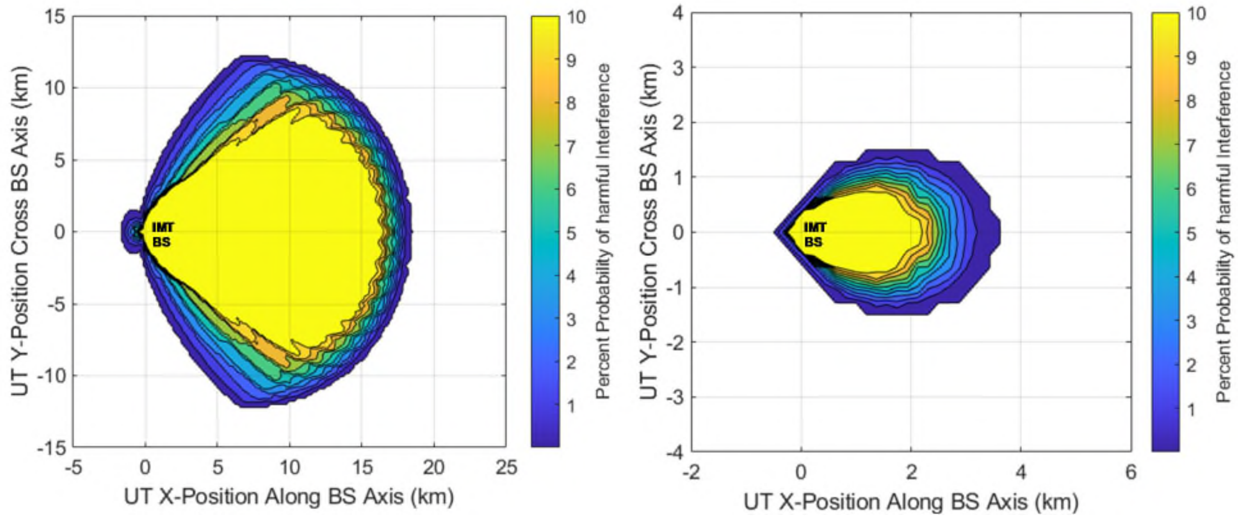

Figure 8: Percent Probability of Harmful Interference using UMFUS maximum EIRP density for Consumer UTs under line of sight conditions (left) and with clutter loss (right)-note different scales

CONCLUSIONS

Harmful Interference from a limited scenario of a single IMT BS in an access link situation into SBCS UTs can occur at distances of 1.2 km when line of sight is possible and for all SBCS UT pointing directions, even when utilizing ITU IMS BS characteristics and UE distribution statistics. Yet this is not representative of what impact from UMFUS deployments, which can be deployed in numerous ways not represented in the ITU studies and with greater power, more liberal base station antenna characteristics, and other operational parameters not captured by the ITU studies.

With inclusion of clutter loss -- which may apply in some situations, such as dense urban hotspots -- the harmful interference area decreases significantly however an SBCS UT would still receive harmful interference out to 0.4 km from just a single base station. Such large harmful interference areas around even a single IMT BS would significantly constraint deployment of IMT BSs or SBCS UTs or both.

Interference from multiple base stations would result in a cumulative effect to the resultant harmful interference regions that would be significantly larger than that shown in this analysis. Given the reported IMT BS densities for various environments, harmful interference from multiple base stations could be significantly greater than that shown in this analysis.

UMFUS allowable EIRP density is nearly 30 dB higher than the IMT BS EIRP density used in ITU analyses when assuming the same antenna and deployment characteristics as IMT. Therefore, at the permitted UMFUS BS EIRP levels, harmful interference is possible out to the horizon in line of sight environments. Even when clutter loss is assumed representing dense urban environments, the harmful interference area can extend out to 3.5 km due to interference from a single base station. This result would be magnified if were the other degrees of freedom that UMFUS users would have at their disposal beyond the limited IMT BS scenario than has been studied in this analysis.

REFERENCES:

ITU-R F.1245-2: Mathematical model of average and related radiation patterns for line-of-sight point-to-point fixed wireless system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz

ITU-R M.2101-0 Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies

ITU-R P.2108 Prediction of Clutter Loss

ITU-R F.758-6 System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference

ITU-R F.699-7 Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

ITU-R P.452-16: Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz

ITU WP 5D/258(Rev 2): Adjacent band compatibility studies of IMT-Advanced systems in the mobile service in the band below 1 518 MHz with respect to systems in the mobile-satellite service in the frequency band 1 518-1 525 MHz

ITU 5-1/31: Reply liaison statement to Task Group 5/1 - System parameters and considerations in the development of criteria for sharing or compatibility studies

ITU 5-1/89: Liaison statement to Task Group 5/1 (copy to Working Party 4B for information) - FSS/BSS technical parameters for sharing studies under WRC-19 agenda item 1.13